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ONTARIO GEOLOGICAL SURVEY

Open File Report 6037

Precambrian Geology, Garden Lake Area

by

T.R. Hart

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Map P.3423 – Precambrian geology, Garden Lake greenstone belt (east half) ..... (back pocket)

Abstract

The Garden Lake greenstone belt is located approximately 150 km north of Thunder Bay, and west of Lake Nipigon. Supracrustal rocks of the eastern portion of the belt extend for approximately 45 km along an east strike, with a maximum width of 8 km at the eastern end and about 4 km in the west. The eastern end is covered by Keweenawan diabase sills and glacial moraine deposits, and the western contact is irregular with a number of thin remnants of metavolcanic extending in to the granitoid rocks beyond the current map area.

The belt consists of a sequence of east trending, predominately mafic pillowed to massive flows with minor interbedded intermediate and felsic metavolcanic tuffs and volcaniclastics, interflow chert – magnetite iron formation, with a central band of conglomerates, graywackes and argillites. These supracrustal units are bounded by moderately foliated to gneissic granitoid rocks consisting of monzogranite, granodiorite to tonalite, with minor quartz diorite and rare gabbroic and amphibolitic bands, and minor dykes intruding the metavolcanics. Two spatially associated gabbro intrusions intrude the metavolcanic rocks east of Garden Lake along the Mooseland River, and a small pyroxenite intrudes west of Garden Lake. Massive, generally uniform monzogranite to granodiorite is located northwest of Garden Lake, southwest of Kearns Lake, and south of Ruffo Lake. A small area of reddish brown shale of the Proterozoic Sibley Group outcrops on the eastern edge of the belt. Discontinuous diabase sills of the Logan Sill Complex overlie all other units in the eastern half of the Garden Lake belt. Much of the area is covered by till and boulder till with variable amounts of sand. A thick moraine covers the eastern end of the belt resulting in a loss of bedrock exposure.

Metavolcanic and metasedimentary rocks of the Garden Lake belt are generally weakly carbonatized, with localized areas of higher carbonatization and/or silicification commonly associated with the highly fractured or intensely sheared units within the late structures. Intense silicification is also present in originally more permeable units in the area north of Garden Lake, associated with the sulphide mineralization. The metavolcanic and metasedimentary rocks of the Garden Lake belt range from a central zone of lower greenschist to a marginal zone of upper greenschist to lower amphibolite facies.

Supracrustal rocks of the Garden Lake belt have been tilted, either about a very large regional scale fold axis or by thrust faulting, resulting in a homoclinal east striking, south-facing sequence. Foliations are moderate to well developed subparallel to the primary structures. Faulting associated with this folding event was conformable to stratigraphy and led to the development of large, belt scale fault zones such as the Garden Lake Deformation Zone (GLDZ). The GLDZ has been active a number of times preceding and following emplacement of the granitoid rocks. A series of northeast and northwest trending faults offset stratigraphy within the belt and are evident in the adjacent granitoid rocks. The lithogeochemistry and field data suggest that the homoclinal attitude of the metavolcanic and metasedimentary rocks could be a result of thrust emplacement of the volcanic rocks (a wedge of back arc oceanic crust) on to a pre-existing volcanic sequence (possibly an island arc with a continental basement).

The Garden Lake belt has the potential to host gold, PGE, and VMS mineralization, and a number of areas are unexplored, or have been explored to a limited extent and are still considered to have potential to host significant mineralization. Gold mineralization is localized along late ductile and brittle structures associated with the iron carbonate alteration, sulphide minerals, and commonly quartz veining. Two environments with the potential to host volcanogenic massive sulphide (VMS) mineralization are the altered mafic metavolcanic rocks and associated iron formations along the north side of the belt, and the thin FII-FIIIa type felsic tuffaceous unit located south of Kearns Lake. The gabbro intrusions and the pyroxenite have the potential to host platinum group mineralization.

Precambrian Geology, Garden Lake Area

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Ontario Geological Survey
Open File Report 6037
2000

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Introduction

The Garden Lake area is located approximately 150 km north of Thunder Bay, and west of Lake Nipigon (Figure 1). The eastern end of the greenstone belt, bounded by latitudes 49°28'N and 49°37'N and by longitudes 89°31'W and 90°07'W, was mapped in 1999. The supracrustal rocks of this portion of the Garden Lake greenstone belt extend for approximately 45 km along an east strike, with a maximum width of 8 km at the eastern end and about 4 km in the west. The eastern extent of the supracrustal rocks is not known as Keweenawan diabase sills and glacial moraine deposits completely cover the belt starting in the area of the Gull River. The western limits of the belt are not well defined, and the contact between the belt and felsic intrusive rocks is irregular with a number of thin remnants of metavolcanic extending beyond the current map area.

Geological mapping in the belt was last completed on a reconnaissance scale by Milne (1964). Recent lithogeochemical sampling indicates that the Garden Lake belt is one of a number of mixed Mesoarchean (>2800 Ma) and Neoarchean (<2800) age greenstone belts in the central portion of the Wabigoon subprovince (Tomlinson et al, 1998). Initial prospecting of the belt occurred in the 1920s, but serious gold exploration did not begin until 1946 (Phelan, 1946). Gold and base metal exploration has been sporadic since that time, and is currently ongoing in the area around Garden Lake.

ACKNOWLEDGEMENTS

The author was assisted by senior assistant Patty Meyer, and by junior assistants Lori Ann Martin, Steven Zurevinski, and Steven Gregory. Ms. Meyer was responsible for approximately one half of all mapping, with Ms. Martin and Mr. Zurevinski assisting in some areas. Mr. John Scott, Resource Geologist in the Resident Geologist's Office, Thunder Bay, provided digital road maps of the area as well as background information on the mineral occurrences.

ACCESS

Access to the map area is by highway 811, which begins at highway 527 approximately 126 km by road north of Thunder Bay, and crosses the eastern third of the belt. The main portion of the belt is accessible by secondary haulage roads built by the Abitibi Consolidated Company exiting highway 811 both north and south of the Mooseland River. An unnamed road south of Garden Lake, the Grew River road and the Hamon Lake road provide access to the south central, north central – southwestern, and western portions of the belt respectively. The Kitchen Lake road provides access to the southeastern portion of the belt, and the Holinshead road provides access to the east portion of the belt. Garden Lake and Kearns Lake are accessible by boat using short portages, and provide access to the rivers flowing into the southern ends of both lakes. However, the Grew River Road has been closed by the Ministry of Natural Resources, west of Garden Lake to restrict access to Kearns Lake. Garden Lake has also been classified as a closed lake for fishing purposes.

PREVIOUS GEOLOGICAL WORK

Initial geological mapping was by W.F. Green (1923) and W.L. Swanson (1923) along the base and meridian lines surveyed by Ontario Department of Lands and Forests in 1922. The Garden Lake and surrounding area was mapped at a 1:63,360 (1 inch to 1 mile) scale by Milne (1964). A 1:126,720 (1 inch to 2 mile) scale mapping program covering the felsic intrusive rocks

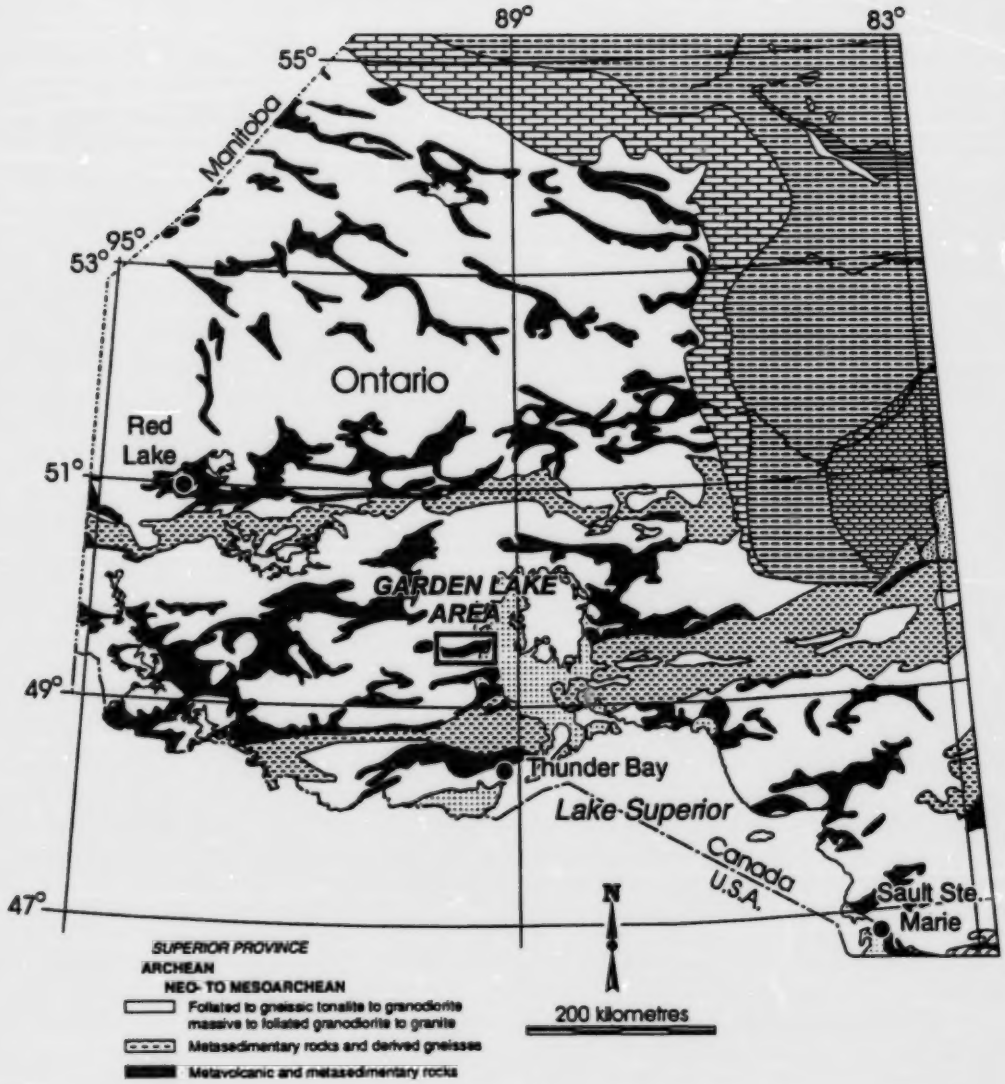


Figure 1. Key map showing location of map area.

surrounding the Garden Lake belt was completed by Sage et al. (1974) and Sage (1998). The intrusive rocks north of the belt were mapped by Percival et al. (1985), and Stern and Hanson (1991). The Garden Lake supracrustal rocks were examined by Thurston et al. (1987) on a reconnaissance scale, in preparation for the Geology of Ontario publications. Lithogeochemical sampling of the mafic metavolcanic rocks around Kearns and Garden Lake for whole rock and Nd isotopic analyses and radiometric age dating was completed by Tomlinson et al. (1996), and Tomlinson et al. (1998).

PRESENT GEOLOGICAL SURVEY

The area was mapped during the summer of 1999. Whenever possible, pace and compass traverses were run perpendicular to the regional geological trend and were spaced about 400 m apart. The outcrop locations were plotted on acetate sheets attached to air photographs at a scale of 1:20,000, with geological field data recorded in a database using Fieldworker software running on an Apple Newton computer. This digital data was downloaded to Fieldlog – ACAD software running on an IBM compatible computer, and geo-referenced by either digitizing the outcrop locations or by downloading GPS positions acquired using a Garmin 12XL averaged by the Fieldworker software. The geological data was overlain on a digital base map at a 1:20,000 scale prepared from the Ministry of Natural Resources Ontario Base Maps.

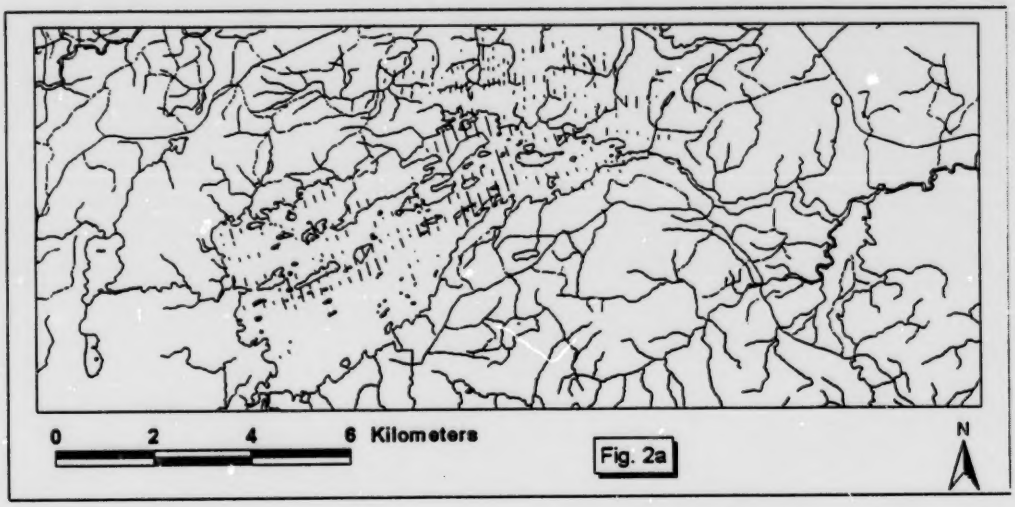
Exploration information on assay results and diamond drill hole logs were obtained from ERLIS and the Assessment Files of the Resident Geologist's Office, Thunder Bay. Diamond drill hole locations were initially obtained from the diamond drill hole database in ERLIS, with minor corrections applied based on examination of the assessment files.

Information for the total field magnetics and second vertical derivative of the airborne magnetometer surveys aided in the interpretation of the field observations (OGS, 1999). Airborne electromagnetic (AEM) and ground induced polarization (IP) survey data conducted by Garden Lake Resources also aided in the geological interpretation (Junnila, 1988, 1989)(Figure 2).

PROSPECTING AND MINING EXPLORATION

The Garden Lake belt was initially explored for gold in the 1920s, which led to the discovery of gold on the east shore of Conick Lake (Milne, 1964). The showing was reported to host visible gold, but no assays were reported. The first documented gold exploration was in 1946 by Little Long Lac Gold Mines Ltd., with work concentrating on the Conick Lake showing and two showings on the southeast shore of Garden Lake (Bluff and Point; Phelan, 1946). There was a hiatus in recorded gold exploration until the eastern end of Garden Lake was staked by prospector C. Bumbu in about 1983. Garden Lake Resources Ltd. optioned the property in 1986, and completed airborne and ground geophysical surveys and detailed sampling and assaying (Junnila, 1988,1989). Claims covering the Bluff, Point and Agar Creek showings were staked by prospectors Stephen and Michael Stares in 1996 and optioned to Battle Mountain Canada Inc. in 1997. Battle Mountain completed a program of prospecting, geophysical compilation, geological mapping, soil sampling and lithogeochemistry (Londry, 1997). The property was subsequently optioned by Band Ore Resources Ltd. in 1999, but the option was abruptly terminated. Greater Lenora Resources Corp. and RJK Exploration Ltd. currently hold the property under option and completed a diamond drill program in the fall of 1999.

Initial exploration for base metals was done by Ruffo Lake Mines with the drilling of a series of targets scattered through the eastern portion of the belt (Stocking, 1962). The



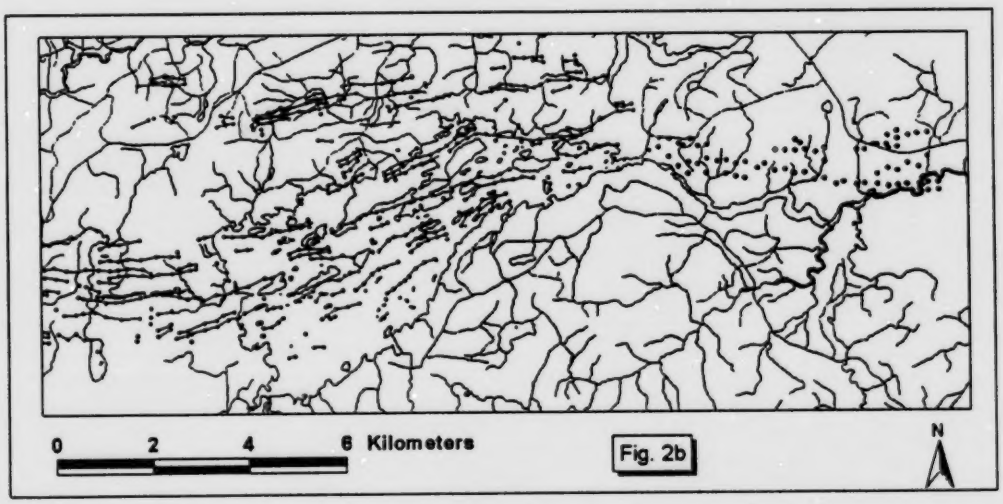


Figure 2a. Induced polarization survey conducted in the Garden Lake area by Garden Lake Resources (Junnila, 1988, 1989).

Figure 2b. Airborne electromagnetic surveys conducted over Garden Lake by Aerodat Ltd. for Garden Lake Resources (Junnila, 1988), and over the eastern Mooseland River by Geoterrex Ltd. for Weaver Lake Resources (Pitman, 1991).

distribution of the holes in areas of little outcrop suggests that the targets being tested were EM anomalies. A second belt wide exploration program for base metals was initiated with an airborne EM and magnetic survey by Inco, Canadian Nickel Company or Canico, in 1963 (Berrer, 1990). The better electromagnetic responses, often those associated with a coincident magnetic high, were investigated by reconnaissance ground magnetometer and vertical loop electromagnetic surveys in 1966. The best anomalies located by the ground surveys were tested by diamond drilling in 1966 and 1967 with a series of drill holes, of which 13 holes are recorded in the assessment files. Starting in 1983, C. Bumbu outlined sulphide mineralization in the area north of Garden Lake. A property covering the mineralization has been explored by two different companies, and by the partnership of C. Bumbu and J. Martin. In 1991, Weaver Lake Resources had an airborne EM and magnetic survey flown in the Mooseland area which outlined a series of EM conductors coincident with the Ruffo Lake drill holes (Pitman, 1991).

PHYSIOGRAPHY

Topographic relief is variable, changing from the eastern end to the western end of the Garden Lake greenstone belt. The eastern portion of the area has a rolling topography influenced by glacial deposits and Keweenawan diabase sills. The sills produce flat topped areas with rare cliffs of up to 30 metres. The best example of this topography is in the area on the eastern edge of the belt, north of the Mooseland River. The western portion of the belt is relatively flat lying with gradual changes in relief and a gentle rolling topography. Diabase sills are absent and the relief is controlled more by glacial deposits and the structural features of the metavolcanic and felsic intrusive rocks. An example of the structural control is the steep sides fault controlled valleys extending south of Kearns Lake. Prominent esker systems cross the belt in a north to northeast direction. There are three main esker systems, east of Garden Lake, on the western end of Garden Lake and west of Kearns Lake, all of which appear to be braided stream systems.

The map area lies on the drainage basin of the Mooseland and Grew Rivers, tributaries of the Gull River. The Gull River drains to the northeast, emptying into Lake Nipigon at Gull Bay. A combination of glaciation and bedrock structural features controls the pattern of lakes and rivers, with an overall east flow.

Outcrop distribution is variable but generally abundant except in the areas of the esker systems, and the moraine deposits at the eastern end of the belt. Outcrops are also scarce in the areas underlain by metasedimentary units and the Garden Lake Deformation Zone, through the central portion of the belt.

General Geology

The Garden Lake greenstone belt is composed of an east trending predominately mafic metavolcanic sequence with minor interbedded intermediate and felsic metavolcanic rocks, chemical and clastic metasedimentary rocks (Table 1). These supracrustal units are bounded by two generations of felsic intrusive rocks, and intruded by a number of small mafic bodies. Mafic metavolcanic rocks consist of mainly massive to pillowed basalt to andesite flows, with lesser pyroclastic and volcaniclastic units commonly of andesite composition. Minor intermediate metavolcanic rocks, consisting of tuffs and lapilli tuffs, and minor tuffaceous conglomerate / debris flows, are interbedded with the mafic metavolcanic rocks. Felsic metavolcanic units, relatively insignificant in the belt, generally occur as tuffs, and less commonly massive flows, in close proximity to the contact with the granitoid rocks and as thin units in the central

Table 1. Table of lithologic units for the Garden Lake greenstone belt.

PHANEROZOIC

CENOZOIC

QUATERNARY

RECENT

Lake, stream, and swamp deposits (unconsolidated)

PLEISTOCENE

Glacial, glaciofluvial and glaciolacustrine deposits; sand, gravel, till (unconsolidated)

UNCONFORMITY

PRECAMBRIAN

PROTEROZOIC

Mafic Intrusive Rocks

Logan Sill Complex diabase

INTRUSIVE CONTACT

Sibley Group

unsubdivided metasedimentary rocks

UNCONFORMITY

ARCHEAN

Intermediate and Felsic Intrusive Rocks[a]

aplite dykes, monzogranite, granodiorite, tonalite, quartz feldspar porphyry

INTRUSIVE CONTACT

Mafic and Ultramafic Intrusive Rocks[b]

gabbro, pyroxenite, hornblende gabbro

INTRUSIVE CONTACT

Foliated to Gneissic Granitoid rocks

aplite dykes, monzogranite, granodiorite, tonalite, quartz diorite, quartz gabbro, quartz feldspar porphyry, feldspar porphyry, mafic gneiss - fine grained gabbro/diorite as continuous layers and/or inclusions[c]

INTRUSIVE CONTACT

Metamorphosed Mafic Intrusive Rocks

gabbro, diorite, gabbro - massive: coarse grained hornblende rich[e]

INTRUSIVE CONTACT

Clastic Metasedimentary Rocks[d]

quartzose arenite, quartzose wacke, argillite, polymictic conglomerate - matrix to clast supported[f]

Chemical Metasedimentary Rocks

oxide facies (magnetite-chert), chert, ferruginous mudstone

Felsic Metavolcanic Rocks

massive flow[g], tuff, tuffaceous conglomerate/breccia

Intermediate Metavolcanic Rocks

massive flow, dike, tuff, lapilli-tuff, tuffaceous conglomerate/breccia

Mafic Metavolcanic Rocks

massive flow[f], pillowed flow, pillow fragment breccia, hyaloclastite breccia, dike, tuff, lapilli-tuff, tuffaceous conglomerate/breccia, massive amphibolite/hornblendite[g], gabbroic amphibolite[h] - moderately to well foliated

a) This unit in part be older than Mafic to Ultramafic Intrusive Rocks.
b) These units are metamorphosed to lower greenschist facies in contrast to the amphibolite facies common in most other units.
c) These rocks may in part be extrusive.
d) These rocks may in part be Timiskaming type clastic sediments.
e) These rocks may in part be intrusive; highly deformed portions of Granitoid rocks.
f) This unit includes rare sections of medium to coarse grained, plagioclase porphyritic gabbro; may in part be intrusive.
g) These rocks are considered to be massive mafic metavolcanic flow metamorphosed to amphibolite facies with total destruction of original textures; but may in part be intrusive.

metasedimentary band. The chemical metasedimentary rocks include various interflow banded chert-magnetite metasediments, cherts and magnetiferous metasediments deposited contemporaneously with both the metavolcanics and the clastic metasediments. The largest accumulation of clastic metasedimentary units, conglomerates, graywackes and argillites, is concentrated in a band along the centre of the belt between Garden and Kearns Lake. Two thinner units are located along the southeastern side of the belt, but are much less extensive.

These supracrustal units are bounded and intruded by a series of mafic to felsic intrusive rocks. An early massive hornblende gabbro unit is generally restricted to the southern margins of the belt between the metavolcanic rocks and the granitoid rocks. The moderately foliated to gneissic granitoid rocks are monzogranite, granodiorite to tonalite, with minor quartz diorite and rare gabbroic and amphibolitic bands. These granitoid rocks are main units bounding the Garden Lake belt and in some areas intruding into the metavolcanic rocks as narrow dykes. Three weakly altered and relatively undeformed mafic intrusive bodies located within the belt have been tentatively placed between the granitoid and massive felsic intrusive rocks. Two spatially associated gabbro intrusions are located east of Garden Lake along the Mooseland River, and a small pyroxenite is located west of Garden Lake. Massive, generally uniform monzogranite to granodiorite is located northwest of Garden Lake, southwest of Kearns Lake, and south of Ruffo Lake. A small area of reddish brown shale of the Proterozoic Sibley Group outcrops on the eastern edge of the belt. Discontinuous diabase sills of the Logan Sill Complex forming ridges of up to 50 m in height, overlie all other units in the eastern half of the Garden Lake belt. Much of the area is covered by till and boulder till with variable amounts of sand. A thick moraine covers the eastern end of the belt resulting in a loss of bedrock exposure.

The metavolcanic and metasedimentary rocks of the Garden Lake belt are generally weakly carbonatized, with localized areas of higher carbonatization and/or silicification. Higher degrees of alteration are commonly associated with the highly fractured or intensely sheared units within the late structures. Intense silicification is present in originally more permeable units in the area north of Garden Lake, associated with the sulphide mineralization. Minor epidote alteration and weak fracture related alteration is also present along the north side of the belt. A close proximity to the contact with the felsic intrusive rocks and an increase in metamorphic grade hinders the separation of the effects of metamorphism and alteration. The metavolcanic and metasedimentary rocks of the Garden Lake belt range from a central zone of lower greenschist to a marginal zone of upper greenschist to possible lower amphibolite facies metamorphism. This zoning is accompanied by an increase in strain towards the southern margin and along the Garden Lake Deformation Zone.

Supracrustal rocks of the Garden Lake belt have been tilted, either about a very large regional scale fold axis or by thrust faulting, resulting in a homoclinal east striking, south-facing sequence. Foliations are moderate to well developed subparallel to the primary structures. Faulting associated with this folding event was conformable to stratigraphy and led to the development of large, belt scale fault zones such as the Garden Lake Deformation Zone (GLDZ). The GLDZ has been active a number of times preceding and following emplacement of the granitoid rocks. An early northwest trend was exploited during intrusion and deformation of the granitoid rocks, and results in an irregular northern margin to the belt. A series of northeast trending regional faults have offset stratigraphy within the belt, may have controlled emplacement of the mafic intrusions and are evident in the adjacent granitoid rocks. A late northwest fault offset the iron formation, and localized intrusion of the diabase.

Mineralization in the Garden Lake belt is localized along late structures, or associated with the iron formations or the late mafic intrusions. Mineralization in the remainder of the map area is

minor and generally restricted to disseminated pyrite and minor pyrrhotite associated with quartz veining.

MAFIC METAVOLCANIC ROCKS

The predominant rock type in the Garden Lake greenstone belt is mafic metavolcanic rocks consisting of mainly massive to pillowed basalt to andesite flows, with lesser pyroclastic and volcaniclastic units, and flow top breccias and pillow breccias common between flows. Rare amphibole rich flow units are interbedded with the massive flows, and as rafted blocks in the granitoid rocks. Distinction of mafic and intermediate metavolcanic rocks in the field was based mainly on the colour index , with the mafic metavolcanic rocks generally being darker green due to higher amphibole and or chlorite contents. This field distinction is largely supported by the thin section examinations and the lithogeochemistry, with the main exceptions being in the volcaniclastic units or the result of alteration.

Massive flows vary from fine grained to medium to coarse grained gabbroic textured to coarse grained amphibolite. The flows range from dark to medium green to gray green on weathered surface and medium to very dark green on fresh surfaces. Individual flows vary in thickness from metres to a few tens of metres, and are commonly interbedded with pillowed flows. The finer grained flows are often feldspar phyric and are the most common flow type in the belt. Coarser grained flows are usually gabbroic textured, may have sparse, coarse grained (0.5 to 1.5 cm), anhedral feldspar phenocrysts or glomerophenocrysts. These flows are more common in the north central portion of the belt, interbedded with pillowed and amphibole rich flows. Some of the gabbroic flows may be intrusive in origin, but where contacts are observed, these flows grade into pillowed flows, or have flow top breccias, indicative of an extrusive origin. Massive flows composed of very dark green, medium to coarse grained amphibole laths are exposed in the north central and north west portions of the belt, closer to the margins of the belt. These flows resemble amphibolites in appearance and may in some case be intrusive in origin. An exposed contact for one of these amphibole rich flows has a pillow breccia between it and the adjacent pillowed flow indicative of an extrusive origin. In thin section, there is little mineralogical difference in the three flow types, with all three composed of plagioclase and hornblende with variable amounts of quartz and sphene. There is no lithogeochemical difference between the massive, massive gabbroic, massive amphibole rich or pillowed flows (*see* "Lithogeochemistry"). Metamorphism resulted in saussuritization of plagioclase, and production of actinolite and chlorite after hornblende (*see* "Metamorphism"). The amphibole rich flows display a higher degree of saussuritization of the plagioclase and the coarser grained actinolite than the gabbroic textured flows. Along the margins of the belt, variable amounts of biotite replace hornblende, indicative of a middle to upper greenschist facies regional metamorphism. A finer grained subhedral metamorphic hornblende occurs in some samples from south of Kearns Lake. These rocks also have groundmasses of polygonized, relatively clear feldspar interpreted to indicate a higher metamorphic grade and higher strain regime. Some of the hornblende interpreted to be igneous could be metamorphic and retrograded to middle greenschist facies. Alteration is commonly a variable pervasive to fracture related carbonate.

Flow-top breccias vary from 0.25 to 0.5 m thick, and occur in both massive and pillowed flows. The breccias are most commonly observed in the areas north of Garden and Kearns Lakes, probably as a result of better exposure. Pillow breccias may display a transition from typical pillowed flows to rounded fragments or pillows in a hyaloclastite matrix (Photo 1), or may have sharp contacts with the bounding flows. The breccias are hyaloclastite rich, commonly light to

medium green brown, highly altered and very soft resulting in recessive weathering on both pillowed and massive flows. The hyaloclastite is usually fine to medium grained, elongated fragments, up to 2 cm in length. In the area of the Bumbu showing and with in the trenches of the showing, the breccias may contain sulphide fragments (*see* "Occurrences").

Pillowed flows are dark green to gray green, very fine to fine grained, rarely aphanitic, ranging from a few tenths of a metre to tens of metres thick. The thinnest flow could be classified as a flow top, being three pillows, or approximately 30 to 40 cm, thick located between two massive flows. Selvages are commonly dark green, about 1 cm wide and chlorite rich with little to no hyaloclastic material. Some flows have light brown 2 to 3 cm wide selvages (Photo 1). Individual pillows are commonly 30 to 50 cm long and up to 30 cm thick, commonly poorly shaped and flattened to varying degrees. Stretching of the pillows is commonly on the order of 4:1 on a horizontal surface, with this ratio increasing along the margins of the belt. Total destruction of the pillows occurs in the shear zones forming the Garden Lake Deformation Zone (GLDZ), where deformed pillows resemble chloritic tuffs (*see* "Structure"). Internal textures are rarely preserved even in the relatively undeformed areas, the exception being vesicles in a pillowed flow located in the east central portion of the belt. The generally poorly developed pillow shapes and lack of internal structures resulted in a limited number of reliable top determinations, mainly restricted to the northern or eastern portions of the belt. The pillowed flows are composed of actinolite, plagioclase, epidote, chlorite, with possible minor quartz, generally resembling the finer grained massive flows of the central portion of the belt (*see* "Metamorphism"). The lithogeochemistry of pillowed flows are identical to the massive flow types (*see* "Lithogeochemistry"). Carbonate alteration is common and in the area of the Bumbu Showing, north of Garden Lake, up to 1% very fine grained pyrite may occur in the selvages and interpillow material (*see* "Occurrences"). Minor fine grained sulphides are also observed in pillow selvage along the north east edge of the belt, south of Holinshead Lake.

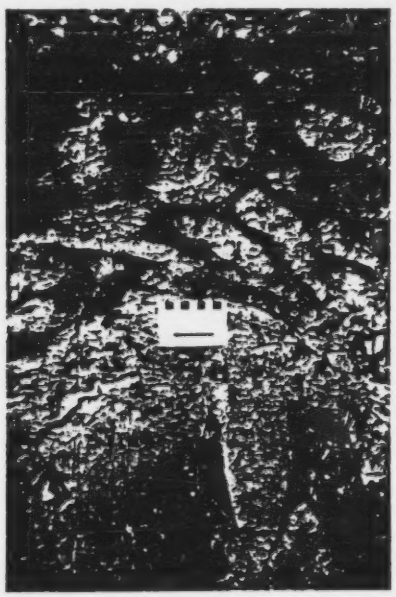


Photo 1. Pillows of bleached light gray basalt with wide brown selvages grading into a brown hyaloclastite rich flow top breccia.

Volcaniclastic tuff to lapilli tuff are medium to light green to gray green on weathered surface and light to medium green on fresh surfaces. The tuffs range from ash to crystal rich lapilli with the crystals being fine grained, anhedral to subhedral white feldspar. In a rare case, glass shards are preserved in an ash tuff located north of Garden Lake. Tuffs are the most common fragmental unit in the belt, and are commonly only a few metres thick, interbedded with the massive to pillowed flows. Internal structures in the tuff beds are rare, and none provide useful top indicators. The tuffs are finer grained rocks mineralogically similar to the massive flows with a moderate foliation and rare coarser phenocrysts of hornblende interpreted to be igneous in origin. The few analysed tuffs geochemically resemble the massive flows (*see* "Lithogeochemistry"). Tuff units near the south margin of the belt, south of Kearns Lake, have polygonized feldspar less clouded by epidote. This clear feldspar in the tuffs and flows is a function of the amphibolite facies metamorphic grade along the margins of the belt (*see* "Metamorphism"). The higher metamorphic grade is also evident in a series of interbedded, well foliated tuffs and massive, coarse grained amphibole rich gabbroic textured flows, along the creek south of Kearns Lake. This higher metamorphic grade is probably a result of contact metamorphism in close proximity to the granitoid contact. Pervasive carbonatization, varying from weak to moderate, and rare extensive silicification led to the misidentification in the field of a few mafic tuffs as intermediate tuffs.

There are a number of distinctive crystal rich tuffs located along the north shore of Garden Lake and in the area between Agar and Kearns Lake. These units contains 15 to 20% coarse to very coarse, white to light green, subhedral to euhedral feldspar. The feldspar occurs in a light to medium green mottled groundmass, resulting in a field classification as intermediate tuffs. Lithogeochemical results of a sample of this material are indistinguishable from the massive mafic flows or the non-porphyritic tuffs. A series of crystal tuff exposures, northeast of Kearns Lake, appear to define a single horizon 3 to 6 m thick. North of Garden Lake, a number of similar 3 to 6 m thick crystal tuff horizons are exposed. This distribution may be a result of exposure, or could indicate that the greater number in the area of Garden Lake represents proximity to the vent.

Mafic metavolcanic rocks with andesite composition occur as a number of tuffaceous units on the southern side of the belt (*see* "Lithogeochemistry"). These units are commonly light green to gray green on weathered surfaces, but can not always be distinguished based on their colour index. One of the andesitic units is a reddish green to very pale green, finely bedded to laminated, very fine grained tuff at the Gate showing on the Kitchen Lake road (*see* "Occurrences"). This unit was initially identified as a felsic to intermediate tuff similar to the felsic tuffs south of Kearns Lake. This unit is composed of quartz and feldspar, with the feldspar replaced by sericite and epidote. Chlorite and actinolite occur in very fine turbid bands that may be highly altered glassy or highly sheared scoria fragments. The laminated appearance of this unit is interpreted to be a result of proximity to an east trending fault (*see* "Structure").

A series of tuffaceous conglomerates, or debris flows, classified as mafic based on the dominant clast composition, and are best preserved on the northern side of the belt. These units grade laterally into intermediate tuffaceous conglomerates to the west. The tuffaceous conglomerates are best exposed along the western access road into Garden Lake with minor interbedded tuffs, and bounded by massive flows to the north and chemical sediment to the south. These conglomerates include units with monolithic aphanitic basaltic clasts containing <1% well rounded chert clasts, units with mixed aphanitic and gabbroic clasts, and units containing about 5% well rounded chert and quartz vein clasts, and mafic clasts with gabbroic, feldspar porphyritic and aphanitic textures (Photo 2). Rare, small, sulphide rich clasts are found in the more

heterolithic beds. In the monolithic beds, well rounded clasts are totally bleached or have bleached rims and may contain garnet within the bleached rims or in fractures. Individual beds are 2 to 5 m thick, and poorly bedded with a very coarse scale normal grading indicating tops to the south. The interbedded tuffs in this sequence are highly chloritic, dark green and generally 20 to 40 cm thick, but also occurring as 5 to 7 cm wide beds in the conglomerates. Two of the thicker beds are well exposed, and they contained disseminated garnet interpreted to indicate an intermediate composition or a high degree of alteration. The matrix in all cases is intermediate in composition with a mineral assemblage dominated by biotite, and 5 to 10% quartz and 5% disseminated, fine grained, dark red garnet. Thin section examination indicates that the matrix consist of an assemblage of quartz, albite, actinolite, chlorite, sericite, epidote, and garnet indicative of an upper greenschist regional metamorphic facies (*see* "Metamorphism"). The garnets occur as anhedral grains with internal structures indicating rotation during metamorphism and deformation, and localized along late fractures. All of the units are cut by fine fractures filled with albite and quartz, which diminish in frequency with distance from the felsic intrusive contact. The more southerly conglomerates are probably laterally equivalent to the intermediate tuffaceous conglomerates located north of Kearns Lake, as both units are bounded by iron formation (*see* "Intermediate Metavolcanics"). The tuffs and lapilli tuffs north of the intermediate conglomerates at Kearns Lake also display a metamorphic and alteration style similar to the conglomerate units north of Garden Lake.

Lenses of amphibolite, tens to a few hundred metres in size, occur within the felsic intrusive rocks near the margins of the belt. These lenses are composed of foliated, fine to medium grained, dark green and white amphibole and feldspar along the margins changing to a highly altered to amphibole and biotite rich, gabbroic textured, massive unit intruded by numerous felsic intrusive dykes in the core. These lenses are interpreted to be pieces of highly metamorphosed and deformed mafic metavolcanic rock detached from the belt by intrusion of the

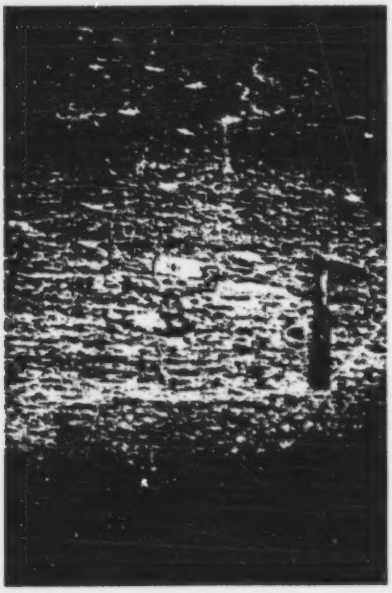


Photo 2. A poorly sorted, heterolithic mafic tuffaceous conglomerate containing <1% chert and <<1% small sulphide clasts. Note the north-south albite and quartz filled fractures cross cutting the east-west foliation. Located north of Garden Lake.

granitoid rocks. An example of this type of lens occurs north of McMullen Lake, on highway 811, with a less deformed core closely resembling the metavolcanic rocks. The amphibolite margins of this lens closely resemble the gabbros of the metamorphosed mafic intrusive units.

Tuffaceous conglomerates with rounded, matrix supported, heterolithic clasts, and a lack of structures indicative of a hot emplacement temperatures, were probably formed by epiclastic processes, either reworked or mass flow origin (Cas and Wright, 1987). The clast compositions indicate that the source for the tuffaceous conglomerate units may be a result of slumping of local flows. The sequence is truncated to the north, and the flows appear to overlie the conglomerates indicating a possible hiatus in eruptive activity. A predominance of pillowed and massive flows with only minor tuffs is indicative of a deep water submarine basaltic eruptive environment (Cas and Wright, 1987). A submarine environment, with a high heat flow, is supported by the presence of a number of interflow chert horizons.

INTERMEDIATE METAVOLCANIC ROCKS

Intermediate metavolcanic rocks are predominately tuff and lapilli tuff, with minor coarse volcaniclastic units and thin massive flows interbedded with the mafic metavolcanic rocks. Tuffaceous conglomerate units are restricted to north of Kearns Lake. The intermediate metavolcanic rocks were distinguished based on a lighter colour and commonly higher biotite content in units closer to the margins of the belt. Intermediate metavolcanic units are more prominent in the southern half of the belt, but this may in part be a result of better exposure conditions. The lack of exposure hinders interpretation, and structural information identified on regional magnetic surveys and Landsat images were used to help define the units (OGS, 1999).

The tuffs are very fine to fine grained, unsorted with little to no internal structure, and typically form beds less than a metre to a few metres thick situated between mafic metavolcanic units. The tuffs are generally light green to light gray green on weathered surfaces and pale green on fresh surfaces. The tuffs are distinguished from the mafic flows based on colour and a better developed fabric. This distinction is unreliable though in the GLDZ, where lithogeochemistry indicates one of the lighter coloured tuff beds is andesitic rather than dacitic (*see* "Lithogeochemistry"). In the lower greenschist facies metamorphism of the central portions of the belt, the tuffs consist of albite-muscovite-chlorite, with minor actinolite. Biotite appears in units close to the margins of the belt, indicating an upper greenschist facies metamorphism (*see* "Metamorphism"). The tuffs are variably carbonatized and/or weakly silicified, with extensive carbonatization observed in the units within and next to the GLDZ.

Intermediate lapilli tuff units are less common than tuffs with the best examples north of the Mooseland River and south of McMullen Lake. The lapilli tuff north of the Mooseland River consists of a number of beds distinguished by slight variations in the mafic mineral content. The clasts appear to be subrounded and highly flattened, 2 to 4 cm in size, and compositionally very similar to the matrix, making identification difficult. In thin section, the unit consists of albite-muscovite-chlorite with minor biotite, actinolite, and quartz. The biotite, actinolite and chlorite occur in irregular, highly turbid areas possibly after glassy fragments. A thin 10 to 15 cm thick horizon with minor magnetite is located along the south edge of the outcrop, close to the contact with the diabase sill. This horizon is interpreted to be a magnetiferous mudstone or argillite rather than a chert. The lapilli tuff south of McMullen Lake contains 2 to 6 cm intermediate clasts in a feldspar phyric, chlorite rich matrix. In thin section, this unit has albite phenocrysts and minor quartz phenocrysts, in a very schistose feldspar, muscovite, and quartz groundmass resembling a crystal tuff. Rare bands 2 to 3 cm in width, with a dark gray to black colour possibly representing a higher graphite content, are found on the south side of the outcrop area. This area is along strike

with the AEM conductors identified by the airborne survey completed by Weaver Lake Resources (Pitman, 1991).

A series of tuffaceous conglomerates are located north of Kearns Lake. The units are situated between mafic tuffs and flows and iron formation to the north, and mafic flows and tuffs and iron formation to the south. The conglomerates include monolithic and heterolithic matrix-supported units interbedded with intermediate tuff, feldspar crystal tuff, and ash tuff forming an approximately 100 m thick sequence. This series of units is interpreted to represent at least two debris flow sequences consisting of ash rich base surges, heterolithic lower units, and monolithic upper units, possibly capped by tuffaceous beds. The ash tuff beds are 10 to 15 cm thick, finely bedded (1 to 2 mm) and light green to slightly darker green colour variations distinguishing the beds. One ash bed appears to be cross bedded in the central outcrop with tops to the south, and may grade laterally to a feldspar phyric mafic tuff bed. The mafic tuff is fine grained, dark green on weathered surface, medium gray on fresh surfaces. The heterolithic units contain fine grained mafic cobble to pebble clasts varying from dark green to medium green, intermediate buff coloured clasts, and minor feldspar phyric intermediate, and minor iron stained clasts. The clasts are subrounded to subangular and are no sorted. In thin section, the matrix is intermediate in composition resembling a feldspar crystal tuff, composed of albite, epidote, biotite, chlorite, garnet, and quartz. The garnet is these units, and the adjacent mafic metavolcanic rocks, is related to an increase in metamorphic grade next to the felsic intrusive rocks about 100 to 200 m to the north. The monolithic units have clasts and matrix that are buff to white weathering, hindering distinction of clasts and matrix (Photo 3). The clasts are subangular, unsorted and include intermediate feldspar phyric clasts with rare (<1%) chlorite and sulphide clasts. A thin section of this matrix is similar to the heterolithic units except for a lack of garnet and the occurrence of minor quartz phenocrysts. The feldspar porphyritic intermediate unit contains abundant feldspar phenocrysts suggesting a tuffaceous origin rather than a flow. This unit may be the cap to the debris flow sequence or form part of the base of the next sequence. About 30 to 40 metres to the south of the exposed conglomerates are a series of outcrops with intermediate feldspar phyric tuffs interbedded with a gabbroic textured massive mafic flow. The iron formations bounding the debris flows have been correlated with the iron formations located north of Garden Lake. The similarities in matrix mineralogy, and stratigraphic position compared to iron formations (*see* "Chemical Metasedimentary Rocks") are interpreted to indicate that the intermediate tuffaceous conglomerates and the mafic conglomerates north of Garden Lake are laterally equivalent.

Photo 3. Monolithic intermediate clasts, subangular to subrounded, in an intermediate matrix, the monolithic portion of the tuffaceous conglomerate / debris flow sequence located north of Kearns Lake.

A few massive flows and dykes of intermediate composition were identified in scattered locations. The massive flows are rare, very fine grained, light gray green to medium green units generally less than a metre to a few metres thick. These units may be less well foliated examples of the tuffs, but exposures are generally poor, hindering identification of primary structure. The dykes are very fine to fine grained and less than a metre in width. These units are commonly located close to the margins of the belt, and may be fine grained dykes of felsic intrusive rocks rather than metavolcanic in origin.

The occurrence of intermediate metavolcanic rocks as generally thin fragmental units in a predominantly mafic metavolcanic sequence suggests a distal volcanic source. Tuffaceous conglomerates with subangular to rounded, matrix supported clasts, and a lack of structures indicative of a hot emplacement temperatures, were probably formed by epiclastic processes, either reworked or mass flow origin (Cas and Wright, 1987). The subangular shape of the clasts in the monolithic beds may indicate a proximal source. Reduction in the degree of angularity is not a definitive indication of a greater distance of transport and mass flows may transport clasts tens to hundreds of kilometres in a submarine environment (Cas and Wright, 1987).

FELSIC METAVOLCANIC ROCKS

Felsic metavolcanic units in the Garden Lake belt generally occur as tuffs, and less commonly, massive flows, interbedded with mafic and intermediate metavolcanic rocks in proximity to the contact with the granitoid rocks. Felsic metavolcanic rocks are largely confined to the southern portion of the belt or as thin units in the central metasedimentary band, with the highest concentration observed in the area south of Kearns Lake. A singular occurrence of a tuffaceous conglomerate is located in the northeast part of the belt. The felsic metavolcanic rocks were distinguished in the field by a pale green to buff and highly siliceous nature. These units are volumetrically a very minor part of the metavolcanic rocks.

Felsic metavolcanic tuff beds are usually 0.5 to 2 m thick and are moderately to highly foliated to sheared so that original textures are rarely preserved. These units are light gray to buff to reddish green gray on weathered surface and medium to light gray on fresh surfaces. In thin section, the tuffs are composed of albite-quartz-muscovite with variable amounts of microcline and minor chlorite-epidote. Some tuff beds are very fine grained, and composed of predominately of quartz with lesser muscovite. Lithogeochemistry indicates these tuffs are silicified tuff horizons, or cherts with a high tuffaceous component (*see* "Lithogeochemistry"). These units are highly altered and difficult to classify, but appear to be similar to the thick sequence of tuffs south of Kearns Lake.

The thickest series of felsic metavolcanic rocks is a 15 to 20 m thick sequence of tuffs exposed along the road SW of Kearns Lake. These tuffs are reddish-gray to gray-green, finely bedded to laminated, fine to very fine grained with no evidence of sorting in the thicker beds (Photo 4). In thin section, these tuffs are composed of quartz, albite, muscovite, and epidote with minor microcline. The quartz and albite are polygonized, and the quartz forms polygonized lenses and bands. This unit is silicified, but has a tholeiitic trace and rare earth element (REE) abundances and ratios in an FII – FIIIa range (*see* "Lithogeochemistry"). Minor carbonate occurs along fractures. There are minor, less than a metre wide, intermediate tuffs interbedded with the felsic tuffs on the north side of the outcrop. A late gabbro dyke about 1.5 m wide, along the north side of the outcrop, cuts the tuff at an angle oblique to the bedding.

Felsic tuffs are interbedded with the central metasedimentary band on the west end of Garden Lake. These tuffs are a quartz-feldspar-sericite schists probably formed from crystal rich tuffs. Thin sections indicate that these units are composed of quartz-albite-microcline with sericite after the feldspars and minor late anhedral carbonate. This is much less recrystallization of the quartz and feldspar compared to the other felsic units, hindering comparisons. Lithogeochemical results for these units indicate a calc-alkaline affinity, clearly distinguishing these units from the other felsic metavolcanic rocks. There is also little difference in the mineralogy to distinguish these units from an altered, fine clastic metasedimentary rock.

A singular exposure of siliceous volcaniclastic rocks is located in the northeastern portion of the belt, north of the Mooseland River. This unit is composed of flattened clasts of quartz porphyritic to feldspar porphyritic material in a fine to medium grained, medium gray quartz - sericite rich groundmass. In thin section, the matrix appears is composed of anhedral to subhedral quartz and feldspar phenocrysts in a groundmass of quartz-feldspar-muscovite-minor chlorite resembling a crystal tuff. Mineralogically, the matrix is similar to a lower metamorphic grade version of the matrix of the tuffaceous conglomerates located along the north west margin of the belt (*see* "Mafic Metavolcanic Rocks"). Quartz porphyritic clasts are predominant, but this unit may be a lateral facies variation of the mafic tuffaceous conglomerates north of Garden Lake. The unit is observed in only one small outcrop, but could be part of a larger sequence of volcaniclastics if it is in contact with the intermediate lapilli tuff to the south (*see* "Intermediate Metavolcanic Rocks").

A few more massive, fine grained beds with no obvious tuffaceous textures were tentatively identified as massive flows. These units are generally less than a metre wide, white to buff, and difficult to trace laterally. Located close to the contact with the granitoid rocks, these units could

Photo 4. Finely laminated, silicified, pink to pinkish gray felsic tuffs forming a sequence 15 to 20 m thick; the thickest occurrence of felsic metavolcanic rocks in the belt. South of Kearns Lake.

be highly deformed dykes of felsic intrusive rock, as observed in the trenches of the Point Showing within the GLDZ. Lithogeochemical sampling would be a useful in distinguishing felsic metavolcanic and felsic intrusive dykes.

The thin, generally tuffaceous nature of the felsic metavolcanic units within a predominantly mafic metavolcanic sequence indicates deposition distal to the felsic volcanic centre. The siliceous volcaniclastic may be epiclastic in nature, as with the other tuffaceous conglomerates, but the single exposure not sufficient to allow a more detailed interpretation. Occurrence of felsic metavolcanic rocks in a predominantly submarine mafic metavolcanic sequence indicates proximity to an island arc or anomalous rift related volcanic centre (e.g. Iceland, Galapagos).

CHEMICAL METASEDIMENTARY ROCKS

The chemical metasedimentary rocks include various interflow metasediments, cherts and magnetiferous metasediments. The interflow metasediments consist of banded chert-magnetite iron formation most prominent along the northern and southern margins of the belt in the area of Garden and Kearns Lakes. The cherts and magnetiferous metasediments are thin beds only rarely observed in areas of better exposure. Chert – magnetite iron formation is interbedded with the clastic metasediments of the central metasedimentary band, indicating that the chemical metasediments are contemporaneous with both metavolcanic and metasedimentary units.

Interflow chemical metasediments are predominately oxide facies banded iron formation consisting of 1 to 5 cm wide beds of medium to light gray chert and black to dark gray magnetiferous chert in units typically 5 to 30 cm thick. The best undeformed examples are the 5 to 10 cm thick beds, situated on top of flow top breccias and as inter-pillow units in the trenches of the Bumbu Showing. Commonly, the units are highly attenuated and rarely traceable along strike for more than a metre. The airborne magnetic survey completed by Garden Lake Resources indicates approximately 4 stratigraphically stacked iron formation horizons in the area of Bumbu Showing that may be traced intermittently to the east, into the area of the Conick Lake Showing. Iron formation is present in the trench of the Conick Lake Showing as a 20 to 30 cm wide unit. Further to the east, along strike, a 25 cm wide lenses of iron formation only one metre in length is hosted by mafic flows. A similar, highly attenuated and folded iron formation is present on the road south of Kearns Lake. This unit is 30 to 40 cm wide and tightly folded with the folding interpreted to be a result of a possible sinistral motion along the GLDZ (Photo 5; *see* "Structure"). There are difficulties tracing this southern iron formation, but the few exposures and the regional airborne magnetic data suggest a single horizon along the south west margin of the belt extending as far as Loganberry Lake (OGS, 1999).

The iron formation becomes thicker west of the trenches of the Bumbu showing, north of Garden Lake. In this area, the iron formations are commonly 1 to 3 m, and up to 7 m wide, but are as difficult to trace along strike as the thinner interflow units. The composition of these thicker units is the same as the thin interflow chert-magnetiferous chert units. Individual beds are usually brecciated and traceable for less than a metre. The sulphide mineral content in these areas is also higher, but appears to be secondary and hosted by fractures and shears (*see* "Occurrences"). It is not clear whether the greater thickness of these units is an original feature or a structural thickening. A structural thickening would be in contrast to the high degree of attenuation to the east. Similarities in the metavolcanic rocks, and airborne magnetic data (OGS, 1999), indicate that the thick iron formation units north of Garden Lake can be traced west, through the intervening felsic intrusive rocks, to the area north of Kearns Lake.

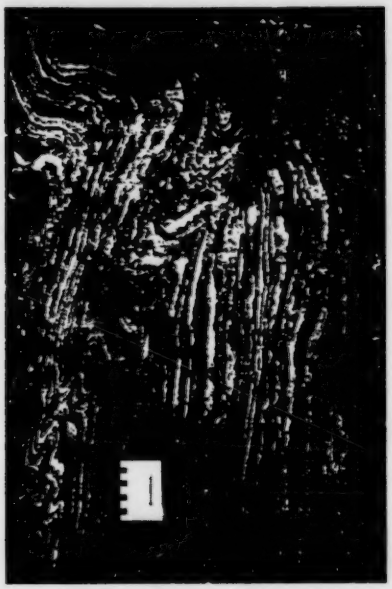


Photo 5. Interflow banded chert-magnetite iron formation with tight folding resulting from a possible sinistral displacement along the Garden Lake Deformation Zone. Southeast of Kearns Lake.

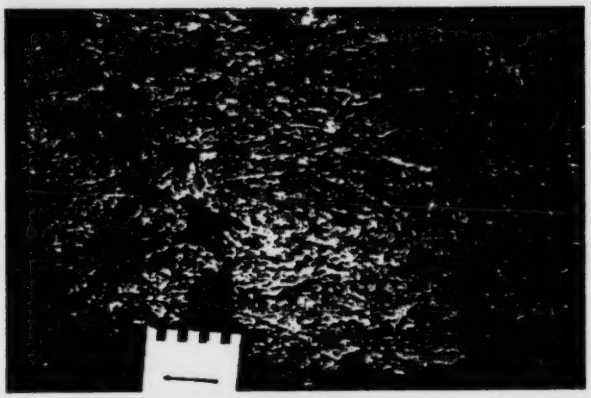


Photo 6. Discontinuous beds of chert and magnetiferous chert interbedded with siltstone. Located north of Kearns Lake, and south of the intermediate tuffaceous conglomerate / debris flow.

There are two iron formation units exposed north of Kearns Lake, bracketing the intermediate tuffaceous conglomerates. The northern unit, exposed on the side of the road, is a banded chert - magnetiferous chert iron formation similar to the units north of Garden Lake. The southern unit consists of magnetiferous chert interbedded with medium gray, fine to very fine grained siltstones (Photo 6). The siltstone and chert beds range from less than a centimetre to a few centimetres in width, are broadly folded, faulted, and rarely traceable for more than a metre. These iron formations appear to continue to the west, but could not be traced for any distance due to a lack of exposure and detailed airborne magnetic data.

Thin beds of oxide facies iron formation are present in the central sedimentary band, interbedded with argillite and graywacke on an island on the eastern side of Kearns Lake. This unit consists of well bedded chert – magnetiferous chert similar to the thinner interflow units discussed above. The unit is only 20 to 30 cm thick, highly attenuated, and offset along a series of small scale fractures. There is only one observed occurrence of this type in the belt, which is probably a function of the recessive weathering nature of the clastic metasediments.

There are also rare occurrences of interflow chert scattered through the belt. The chert beds are 1 to 5 cm wide, saccharoidal textured, light gray, boudinaged, and rarely banded. These beds occur as either lenses or attenuated beds, which could not be traced laterally. Some of these chert units may be deformed and recrystallized quartz veins, especially in the areas close to the belt margins.

A number of fine to very fine grained clastic beds enriched in magnetite are scattered through the belt, generally associated with areas of higher metamorphic grade. The beds are 2 to 5 cm thick, dark gray to black, very fine grained, with no apparent silicification. A good example of this type of unit is located along the road to Holinshead Lake, associated with the intermediate metavolcanic rocks and close to the contact with the diabase sill. These beds are commonly interbedded with mafic tuffs, but may be either tuffaceous to argillaceous in origin.

The chert – magnetite iron formations are an indication of a high heat flow volcanic environment which formed hydrothermal circulation systems. The hydrothermal systems produced chemical sedimentary beds during breaks in volcanic eruptive activity. These breaks were wide spread wide resulting in deposition of iron formation units traceable the length of the belt. The breaks in eruptive activity appear to have been brief allowing for the formation of thin beds. Thicker iron formation units, and associated alteration of the metavolcanic units (*see* "Alteration"), suggest restricted areas of higher heat flow. Silty beds north of Kearns Lake are interpreted to indicate a higher sedimentation rate, possibly from the same intermediate composition volcanic source producing the intermediate tuffaceous conglomerates found in this area. Hydrothermal activity and deposition of iron formation was continuous during formation of the belt, during deposition of both metavolcanic and clastic metasedimentary units.

CLASTIC METASEDIMENTARY ROCKS

The greatest accumulation of clastic metasedimentary units in the belt is in a band along the centre of the belt between Garden and Kearns Lake. Two thinner units are located along the southeastern side of the belt, but the strike length of these units is not known. Observations and interpretations are limited due to the recessive weathering nature of the clastic metasedimentary rocks. The central band consists of fine to coarse clastic metasediments, with minor chemical metasediments. The eastern occurrences are a conglomerate with sulphide clasts, and a pink pebble conglomerate.

The central metasedimentary band is observed in only five locations, including two exposures on Kearns Lake. Three of the outcrops are a polymictic, matrix-supported conglomerate containing well-rounded to subrounded chert, quartz, felsic and mafic metavolcanic pebble sized clasts, with minor (<1%) granitic to tonalitic and sulphide clasts. The matrix is a sand sized graywacke with abundant well rounded quartz grains (Photo 7). In thin section, the matrix consists of highly polygonal quartz and albite, and fine clasts and bands of sericite. The sericite is probably a replacement of clay minerals in the matrix. None of the outcrops was large enough or well enough exposed to allow for the identification of primary sedimentary structures, so top directions are not known. The clasts are flattened along an east-west foliation, with a high degree of elongation in a steep west plunging direction. The deformation results in a highly foliated, fissile unit. The three widely spaced outcrops on Kearns Lake, south of Agar Lake, and just west of Garden Lake, are interpreted to form a single unit.

Argillite and graywacke observed in one outcrop on Kearns Lake, north of the conglomerate. The graywacke is light gray, quartz rich material similar to the conglomerate matrix. An chert – magnetite iron formation is interbedded with the graywacke (*see* "Chemical Metasedimentary Rocks"). The outcrop on the lake is low, sloping and algae covered making sampling or observation of textures difficult. These units are interpreted to correlate with graywacke and siltstone beds east of the Kearns Lake, east of the road. These graywacke beds are medium gray brown on the weathered surface and medium gray green on fresh surface, 10 to 15 centimetres thick. The argillite beds are more attenuated than the graywacke and generally lighter gray and only 3 to 5 cm thick. There is no indication of sorting or any top indicators, but the exposure is limited to less than a metre square.

The easternmost metasedimentary unit consists of multiple graded beds of a matrix supported pink pebble conglomerate. The pebble clasts are well rounded to subrounded pink quartz-feldspar and white quartz-feldspar plutonic rocks with flattened medium to dark gray arkose and argillaceous clasts. Individual beds are 20 to 75 centimetres thick and graded from coarse to fine pebbles with tops to the south (Photo 8). The clasts are highly flattened along a northeast foliation, subparallel to bedding, and elongated steeply to the east. The matrix is a medium gray to pinkish gray graywacke containing abundant well rounded quartz grains. In thin section, the matrix consists of quartz-albite-epidote-sericite-chlorite with quartz and albite also occurring as coarser polygonized grains with pressure shadows. The matrix also contains minor, late subhedral iron carbonate, and anhedral opaques concentrated along fractures. Some of the of the matrix may be due to carbonate or hematite staining.

The other eastern metasedimentary unit is a sulphide clast conglomerate exposed in the road bed of the Kitchen Lake road, on a hummock isolated in the middle of a swamp. The conglomerate contains well-rounded to subrounded chert, mafic and felsic metavolcanic, and feldspar porphryritic clasts, with 1 to 2% sulphide clasts. The sulphide clasts are composed of pyrite and minor pyrrhotite. The clasts are contained in a fine grained graywacke matrix with abundant sand size quartz and feldspar grains. Thin, 5 to 20 cm wide, beds of silt or ash are interbedded with the conglomerate. The clasts are slightly flattened along a northeast foliation parallel to the strike of the silty beds. This unit is very similar in character to the tuffaceous conglomerate units located to the north of Garden Lake, and may represent a debris flow. The bedding in the pink pebble conglomerate and the sulphide bearing conglomerate indicate that the two metasedimentary units form separate units within the metavolcanic sequence.

These clast metasedimentary units formed in two apparently discrete depositional environments. The low percentage of chert and plutonic clasts in the conglomerate of the central band indicates a predominantly volcanic source. Transport of the clasts was over some distance,

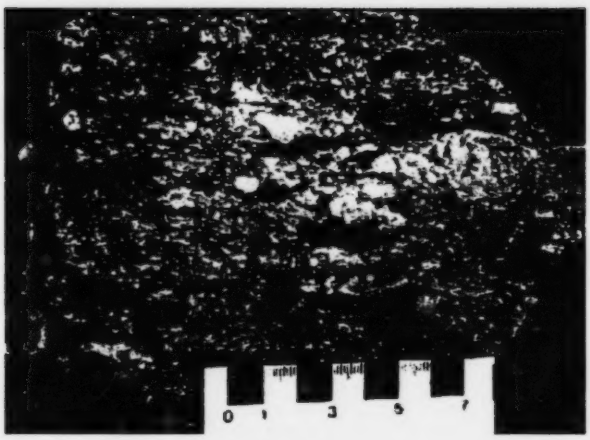


Photo 7. Polymictic, matrix-supported conglomerate containing chert, quartz, felsic and mafic metavolcanic pebble sized clasts, with minor (<1%) granitic to tonalitic and sulphide clasts, in a greywacke matrix. Located on Kearns Lake.

Photo 8. Matrix supported conglomerates containing pink quartz-feldspar and white quartz-feldspar plutonic rocks, arkose, and argillite, in a matrix of greywacke; multiple graded beds with tops to the south. Located south of the Kitchen Lake road.

due to the subrounded to rounded nature of the clasts. These units probably represent a break in eruptive activity, but could have formed later and are unrelated to the volcanic event. The sulphide bearing conglomerate may be a tuffaceous conglomerate deposited in a restricted area, and therefore difficult to trace laterally. The pink pebble conglomerate is probably deposited from a predominantly plutonic source. A possibility that this unit is Timiskaming age was proposed based on the pink colour of the clasts being related to an alkalic geochemistry. This unit lacks the definitive jasper clasts and alkalic volcanic commonly observed in the Abitibi subprovince examples (Jackson and Fyon, 1991).

METAMORPHOSED MAFIC INTRUSIVE ROCKS

Early mafic intrusive rocks are generally restricted to the southern margins of the belt between the metavolcanic rocks and the foliated granitoid rocks. These thick, massive hornblende gabbro have been classed as a separate unit based in textural and mineralogical differences compared to the mafic metavolcanic and mafic to ultramafic intrusive rocks. Contacts with the metavolcanic and granitoid rocks are not exposed.

Early mafic intrusive rocks are massive, fine to coarse grained, composed of dark green amphibole and white plagioclase. Weak to moderate epidote and chlorite alteration of the gabbro is commonly observed in outcrop. There are rare fractures and shearing, and some fractures contain chlorite and/or quartz stringers. No sulphide or oxide mineralization was observed. In thin section, these units are composed of hornblende, actinolite, plagioclase, epidote, with minor chlorite and opaques. The hornblende occurs as phenocrysts, partially to totally replaced by actinolite, in a fine groundmass of feldspar. Plagioclase occurs as fine anhedral grains highly altered to epidote and sericite. There is not alignment of the minerals on a microscopic scale.

The gabbros have been interpreted to be intrusions localized along the contact between the south margin of the belt, and may have formed at about the same time as the granitoid rocks. Some mafic metavolcanic units along the margins of the belt are highly metamorphosed, and closely resemble the gabbros in hand sample. In thin section, the metamorphosed metavolcanic rocks have clear feldspar and subhedral hornblende, in contrast to the altered mineralogy of the gabbros. The amphibole rich flows north of Garden Lake resemble the gabbros, but occur in flows less than 5 m thick. The gabbros form bodies hundreds of metres in size with no observable internal structures indicative of formation from a series of metamorphosed flows. There are lenses of amphibolite consisting of rafted mafic metavolcanic rocks within the granitoid rocks, north of McMullen Lake (*see* "Mafic Metavolcanic Rocks"). These rafted blocks generally have some preserved metavolcanic textures in the cores, in contrast to the uniform textures in the gabbros. The gabbros lack the igneous textures and relict igneous mineralogy of the mafic to ultramafic intrusive rocks within the belt, and are not considered related to those units. An irregular magnetic pattern is present south of the belt, in what has been previously identified as granitoid rocks (OGS, 1999). This area may be the result of partial digestion of a larger block of greenstone, but requires more detailed magnetic data and a field examination to properly assess. The magnetic pattern of gabbro is masked by a flat lying diabase sill, and it is not possible to compare these two areas.

FOLIATED TO GNEISSIC GRANITOID ROCKS

The moderately foliated to gneissic granitoid rocks are monzogranite, granodiorite to tonalite, with minor quartz diorite and rare gabbroic and amphibolitic bands. These granitoid rocks are the main units bounding the Garden Lake greenstone belt and in some areas intrude into the

metavolcanic rocks as narrow dykes. The gneissic granitoid rocks are cut by massive aplite and coarse to very coarse grained quartz-feldspar dykes. Separation of the massive felsic intrusive and granitoid rocks is based on the gross morphological differences rather than observed contact relationships, and the placement of the mafic to ultramafic intrusive units stratigraphically between the two felsic intrusive suites is strictly interpretative. The foliated and gneissic rocks usually occur as separate units with slightly different characteristics, and have been described separately.

Foliated granitoid rocks are medium to very coarse grained granodiorite to tonalite, white to light gray, and resemble more foliated varieties of the massive felsic intrusive rocks. These units are composed of near equant quartz and feldspar with less than 10% mafic minerals, generally biotite and chlorite. In thin section, these units lack the hornblende of the massive felsic suite, generally have polygonal grains of feldspar and quartz elongate along the foliation, and myrmekitic textures are common. These foliated units may form large areas or may be interbanded with the gneissic units on the scale of metres.

The granitoid rocks commonly resemble the more extreme compositions, the monzogranites and quartz diorite to gabbros, which form bands ranging from 0.20 m to more commonly metres in width. The monzogranite gneisses consist of light pink to pinkish gray bands, commonly with feldspar augen. These units are usually interbanded with gneisses granodiorite to tonalite units. The gneissic textures are also evident on a microscopic scale, with alternating quartz and feldspar rich bands and bands richer in biotite and chlorite. Fluxion textures are common. The quartz and feldspar are polygonized, and the feldspar is commonly less clouded than in the massive felsic intrusive rocks. Myrmekitic textures are much more common than in the massive felsic intrusive rocks. The best exposures of the foliated to gneissic granitoid rocks are southwest of Kearns Lake and south of Holinshead Lake.

Two mafic units are associated with the foliated granitoid rocks, an amphibolite and a gabbro. The amphibolite is dark green to black, fine to very fine grained, moderately to well foliated to gneissic and consist of amphibole with biotite and minor quartz. These units commonly occur as bands within the gneissic units with the best exposed examples along both the northeastern and southwestern belt margins. Some of these bands may be septa of metamorphosed, deformed metavolcanic rocks separated from the belt by granitoid rocks. An example is discussed above (*see* "Mafic Metavolcanic Rocks"). Other amphibolite bands are probably highly deformed gabbro to diorite intrusions related more closely to the granitoid rocks. The gabbros are massive to moderately foliated, fine to medium grained, dark green and white, forming conformable bands or cross cutting units. The more massive gabbro units have been emplaced late in the intrusive sequence. In thin section, these units have a hornblende, quartz, plagioclase, epidote, and sericite with minor microcline and chlorite. The hornblende is subhedral and the feldspar forms a clear, anhedral groundmass. The textures are interpreted to indicate an amphibolite facies regional metamorphic grade with no retrograde reactions. The presence of microcline suggests interaction with the more felsic compositions, or some units are diorite to monzogabbro.

Dykes

There are four different types of felsic dykes in the map area, feldspar porphyritic, quartz porphyritic, quartz – feldspar porphyritic, and aplite. The first three types are observed intruding the metavolcanic rocks of the belt in a number of widely spaced locations. These dykes are generally close to the contact between the granitoid and metavolcanic rocks, but a lack of contact relationships or distinctive mineralogy precludes relating them to a specific felsic intrusive unit.

The aplite is intruding the massive felsic intrusive and granitoid rocks and may be from the same source, but there is no obvious textural or mineralogical method to verify this possibility. So separate map units are indicated for the dykes under both the granitoid and massive felsic intrusive rocks.

The highest concentration of felsic dykes was observed in the trenches of the Point and Bluff showings, on the southeast shore of Garden Lake. These dykes are fine to medium grained, white to light gray, and massive with feldspar and/or quartz phenocrysts. An undeformed dyke, intruding at a low angle to the bedding in the western trench of the Point showing, is bounded by an amphibole rich metamorphic halo in the surrounding mafic flows. This pattern of metamorphism is similar to that observed along the margins of the belt. Mineralogically, the dyke is composed of quartz, microcline, albite, and muscovite, with phenocrysts of microcline. The dyke is not altered, and is located outside the shear zone located on the north side of the trenches. In a separate trench at the east end of the showing, a 1 to 1.5 m wide dyke cross cuts a shear within the GLDZ, and displays undulating contacts (*see* "Structure"). This dyke has alkalic trace element and REE abundances and ratios, and a radiometric age of 2708 Ma (Tomlinson et al. 1998; *see* "Lithogeochemistry"). The highly foliated felsic units in the other trenches of the showing have been interpreted as intensely sheared porphyritic dykes.

There are a number of quartz-feldspar porphyry dykes along the western shore of Garden Lake and south of Agar Lake. These dykes are massive, medium grained, light gray to gray brown with coarse grained, subhedral quartz and feldspar phenocrysts. A dyke on the west shore of the lake has a very irregular contact with the mafic flows, apparently intruding along the foliation and is very difficult to trace. The total width of this dyke is not known, but is estimated to be about 1 to 2 m. The dyke is highly fractured with quartz and carbonate stringers and lenses. A dyke observed southeast of Agar Lake, was of indeterminate width. This unit is medium grained, massive, light gray to white and composed of quartz, feldspar and minor chlorite and biotite. The trace element and REE abundances and ratios resemble the massive felsic intrusive rocks (*see* "Lithogeochemistry").

A dyke containing 10 to 15 % euhedral, monoclinic white feldspar crystals up to 3.5 cm in a fine to medium grained, medium gray, siliceous groundmass is located along the stream south of Kearns Lake. The dyke is up to 30 cm wide with a very irregular, bifurcating outline resulting in numerous branches. The groundmass is moderately foliated, and the feldspar crystals commonly have a single fracture offset. In thin section, the groundmass is composed of quartz, microcline, albite, biotite, with metamorphic epidote, muscovite, and chlorite. The biotite laths are aligned along the foliation. Although the feldspar crystals have a monoclinic form, XRD analyses indicate an albitic composition. Minor carbonate occurs along fractures. A similar feldspar porphyry intrusive unit is located along the west shore of Kearns Lake. In that location, the feldspar phenocrysts are medium to coarse grains, and the groundmass displays a higher degree of deformation with the foliation wrapping around the phenocrysts. These dykes are interpreted to be late crystal rich phases of the granitoid rocks found immediately to the west.

Aplite dykes intrude both the massive felsic intrusive and granitoid rocks. The dykes are light pink to light gray pink, very fine grained, sugary textured, and massive, rarely with very coarse grained quartz and/or potassium feldspar zones in the core of the dyke. In thin section, the dykes are composed of quartz, albite, and microcline with metamorphic epidote and muscovite partially replacing the feldspars. The quartz and feldspars form an anhedral polygonized groundmass. Commonly, the dykes are less than 10 cm wide, but may be up to 40 cm wide with the wider dykes usually occurring in the massive felsic intrusive rocks. In the massive felsic intrusive rocks, the aplite dykes commonly following one or more of the joint sets. The dykes in

the granitoid rocks often crosscut the foliation or gneissosity. The best examples of these dykes are in the massive felsic intrusive rocks along the Grew River road, north of Agar Lake.

MAFIC TO ULTRAMAFIC INTRUSIVE ROCKS

There are three mafic intrusive bodies within the belt which are relatively undeformed in comparison to the metavolcanic rocks, and have therefore been interpreted to be younger. Well preserved igneous textures and relict igneous mineralogy distinguish these intrusions from the metamorphosed mafic intrusive rocks (*see* "Metamorphosed Mafic Intrusive Rocks"). There are no observed contacts between these units and the granitoid rocks, so the age relationships are not known. These mafic units have tentatively been placed as older than the foliated but younger than the massive felsic intrusive rocks. Two of the mafic intrusions are spatially associated, lying east of Garden Lake along the Mooseland River. The third mafic intrusion is much smaller in extent, and is located west of Garden Lake.

Gabbro

The westernmost of the two intrusions along the Mooseland River was originally identified by Milne (1964). The two intrusions are separated by a thin screen of mafic metavolcanics. Both intrusions are gabbros consisting of fine to medium grained pyroxene, amphibole and plagioclase with minor leucoxene, with the plagioclase altered to a light green. Variation in the pyroxene and plagioclase contents results in irregular zones of more leucocratic composition. Irregular clots of plagioclase, up to 10 cm in diameter with indistinct contacts, are irregularly scattered through the eastern side of the western intrusion. In thin section, the pyroxene is metamorphosed to actinolite, hornblende, and chlorite. The plagioclase is nearly completed replaced by epidote, probably resulting in the pale green colour in hand sample. The opaque grains are subhedral to skeletal with turbid haloes suggesting alteration of original magnetite to leucoxene. Rare anhedral masses of serpentine may be highly altered olivine.

Igneous layering is present on the eastern side of both intrusions, and consists of alternating 5 to 8 cm layers of pyroxene rich and 2 to 4 cm layers of plagioclase rich bands (Photo 9). In thin section, the relict pyroxene rich layers consist of actinolite, chlorite, hornblende, and epidote. The plagioclase layers are distinguished by a less metamorphically altered, more euhedral grains. In the eastern intrusion, the layers strike northeast with apparent northwest dips. Individual layers can not be traced due to offsets by northwest trending fractures. The total thickness of the layered units is probably less than 20 metres, and the layering occurs within 10 m of the contact with the mafic metavolcanic rocks. The layering in the western intrusion has the same orientation but appears to be further from the wallrock contact.

Rare coarse to very coarse grained hornblende-quartz gabbro lenses occur in the southern portions of both intrusions, close to the contact with the metavolcanic rocks. The lenses are composed of dark green hornblende and white plagioclase, with minor anhedral light gray quartz, beige leucoxene and pyrite. Contacts with the main gabbro are gradual, with the grain size rapidly decreasing over a distance of a few centimetres. The pyrite constitutes less than 1 percent of the rock and occurs as disseminated anhedral grains. Irregular 1 to 2 cm patches of plagioclase and quartz may occur peripheral to the larger lenses. The hornblende gabbro lenses may represent either a late stage fractionate or hydration reactions with the metavolcanic rocks.

Serpentine and quartz-serpentine alteration is common along 0.25 to 0.5 cm fractures. This style of alteration was most noticeable south of the Mooseland River, along the Kitchen Lake Road, possibly a result of better exposures in the logged areas. Shearing and alteration of the

gabbro occurs along the northwest contact of the western intrusion. The shears are up to 2 metres wide resulting in a fine to very fine grained, highly altered more melanocratic gabbro, with relatively sharp boundaries with the non-sheared gabbro. In extreme cases closer to the contacts, the gabbro is strongly sheared and secondary quartz and epidote containing 10 to 20 cm lenses of highly chloritized, fine grained gabbroic material. Fine grained, disseminated pyrite is common within the quartz – epidote altered portions of the shear. The shears generally trend northeast and dip steeply south, with irregular bifurcating outlines. The extreme cases may be the result of interaction between the intrusion and the adjacent metavolcanic rocks.

The contact between the gabbro and metavolcanic rocks is observed along the eastern contact of both intrusions. Irregular narrow dykes of fine to medium grained gabbro intrude relatively undeformed mafic metavolcanics. The metavolcanic rocks display a greater degree of epidotization and chloritization over a distance of 2 to 3 metres, but this assemblage is only slightly higher grade than the surrounding rocks. Metamorphic grades and alteration in the metavolcanics rocks is greater in the areas close to the granitoid contacts than next to gabbro intrusions, which is interpreted to indicate that these intrusions are small bodies.

Pyroxenite

A mafic intrusion of unknown extent was observed in one outcrop west of Garden Lake. This exposure is dark gray-green, coarse to very coarse grained pyroxene and amphibole, with only minor plagioclase. The pyroxenite is magnetic, probably a result of a high magnetite content. In thin section, the unit consists of augite, plagioclase, sericite, actinolite, serpentine and magnetite. The actinolite is replacing the pyroxene. Serpentine is replacing olivine, and commonly occurs in masses rimmed by opaque (magnetite). This unit has been classified as a pyroxenite, but the mineral assemblage falls in the pyroxenite to olivine pyroxenite range. The intrusion is a small magnetic high on the regional airborne magnetic survey (OGS, 1999).

Photo 9. Igneous layering disrupted by late west trending fractures, along the east side of the eastern gabbro intrusive. The contact with the metavolcanic rocks is towards the bottom of the photograph.

The pyroxenite is bordered to the south and east by a coarse grained hornblende gabbro that intrudes the mafic metavolcanic rocks. The hornblende gabbro is composed of coarse grained white feldspar and dark green laths of amphibole with minor quartz. Contacts with the mafic flows are irregular to dyke like, with a no appreciable alteration or metamorphism of the metavolcanic rocks. Quartz veining is common in the hornblende gabbro portion, usually occurring along fractures with minor shearing trending east to northeast. The quartz is usually white with no associated sulphide mineralization, although two veins further east contain minor chlorite or epidote staining resulting quartz with a light green . Bleaching of the gabbro may occur next to the veins suggesting a late age for the quartz. Minor shearing occurred in a 090° joint in one outcrop, with minor associated iron carbonate alteration.

MASSIVE INTERMEDIATE TO FELSIC INTRUSIVE ROCKS

Massive intermediate to felsic intrusive rocks are located northwest of Garden Lake, southwest of Kearns Lake, and as a small body south of Ruffo Lake. Contacts between the massive intrusive and granitoid rocks are not exposed. The massive to weakly foliated, generally uniform monzogranite to granodiorite contrasts with the compositionally diverse foliated to gneissic granitoid rocks. The small body south of Ruffo Lake has a higher biotite content, and remnant igneous textures indicate a different history than the other rocks of this group.

The northwest and southwest areas of massive felsic intrusive rocks consist of predominantly monzogranite to granodiorite with minor tonalite. These rocks are massive, medium to coarse grained, light pink to pinkish gray to white, consisting of near equant feldspar and quartz with generally less than 10% biotite. Weak to very weak epidote alteration is common, usually along joint planes but also after feldspar. These rocks are weakly to moderately jointed. Rare shearing may occur along joints close to the contact with the metavolcanic rocks. The shears may contain chlorite and rarely pyrite. Sulphide mineralization is rare in the massive rocks, other than pyrite in shears and associated with the rare quartz veins. Thin section examinations indicate that the massive intrusive rocks have a quartz, microcline, albite, biotite, hornblende mineral assemblage with epidote and muscovite replacing albite and microcline, and chlorite replacing biotite and hornblende. Albite is metamorphosed much more completely to epidote in these rocks than in the granitoid rocks, interpreted to indicate that it is original igneous albite. Quartz and the feldspars are generally polygonized to varying degrees, and the quartz commonly has a wavy extinction indicative of a moderate degree of strain. A sample of massive monzogranite from north of Garden Lake has trace element and REE abundances and ratios similar to the intermediate metavolcanic rocks and the felsic metavolcanic rocks associated with the central metasedimentary band (*see* "Lithogeochemistry"). Minor occurrences of a pinker phase were observed in some locations close to the contacts with the metavolcanics, north of Garden Lake. There is no direct correlation between microcline content and the pink . The occurrence of hematite along some joints and fractures suggests that the pinker could be a result of alteration. The rare quartz veins are white to gray, commonly 3 to 5 cm wide with variable amounts of albite. Generally, the veins follow one of the joint sets and may have chlorite altered margins with up to 2% fine grained pyrite.

Contacts between the massive intrusive rocks and the metavolcanic rocks are not exposed. Proximity to the metavolcanic contact is often evident by an increase in alteration or the presence of angular xenoliths of mafic material. These xenoliths are commonly less than 10 cm, but may be up to 50 cm, consisting commonly of massive to foliated, highly altered amphibole rich material indeterminate origin. Xenolith contacts are always sharp but the mafic material may have

a hazy appearance and pitted surface suggesting a high degree of alteration. The best examples of xenoliths are along the western access road to Garden Lake and the road north of Kearns Lake.

A small body of massive felsic intrusive rock intrudes the metavolcanic rocks southwest of Ruffo Lake. The body is massive, medium to coarse grained monzogranite to granodiorite, with 5 to 10% biotite and hornblende, pink to white feldspar and quartz. The rocks most closely resemble the massive felsic intrusive rocks northwest of Garden Lake. In thin section, this body contains quartz, microcline, albite, biotite, and hornblende with minor sphene and apatite. The albite occurs as concentrically zoned crystals with minor epidote highlighting the zoning. Hornblende is medium green brown and euhedral and is in equilibrium with the coarse laths of biotite. Microcline forms anhedral oikiocrystic grains with fine inclusions of the other phases. Chlorite is present as a minor replacement after hornblende and biotite. The mineralogy resembles the massive felsic intrusive rocks, but with well preserved igneous textures. Mineralogically, this unit is similar to the granodioritic portions of the sanukitoid suite of the Roaring River Complex located approximately 20 km to the north. The full extent of this unit is not known, having been identified only in 4 closely spaced outcrops and a diamond drill hole completed by Ruffo Lake Mines, in 1962. A hybrid granite described by Milne (1964) as resembling a sheared tonalite or granodiorite, is located about 700 m southeast, and may be part of this body.

SIBLEY GROUP

The Sibley Group sedimentary rocks are red bed sequences preserved in north trending, elongated, fault bounded basins (Sutcliffe, 1991). The sedimentary rocks consist of quartz arenite, red shales and mudstones. These rocks are Proterozoic in age, with a radiometric age of 1339+/-33 Ma (Sutcliffe, 1991), and overlie the Archean metavolcanic and intrusive rocks.

Two small outcrops of Sibley Group shales were observed on the Kitchen Lake road, on the edge of the moraine system covering the extreme eastern edge of the Garden Lake belt. The unit is red to reddish brown, massive, fine to very fine grained with no observed bedding or structure. The eastern outcrop is highly fractured and with a stockwork of beige to white carbonate veins 0.5 to 2 cm in width, containing angular fragments of the metasediment. The metasediment in the western outcrop is cut by a series of stringers and veinlets of quartz and pink feldspar containing small vugs with fine druzy quartz and crystalline specular hematite. Similar veinlets with hematite are observed in the Archean metavolcanic rocks along the Kitchen Lake road (*see* "Alteration"). Occurrences of purple to mauve shales were reported by Milne (1964) along the Mooseland River, immediately north of the outcrops observed along the road.

LOGAN DIABASE SILL COMPLEX

Discontinuous diabase sills of the Logan Sill Complex overly all other units in the eastern half of the Garden Lake belt. These sills are part of a series of olivine tholeiitic diabase dykes, sheets and sills intruding the Sibley Group and Archean rocks in the area about Lake Nipigon. A zircon radiometric age indicates intrusion at 1108+4/-2 Ma (Sutcliffe, 1991). The sills usually form ridges of positive relief of up to 50 m in height. Total sill thicknesses are not certain as lower contacts are commonly covered by glacial material. The elongate direction of many of the sills appears to reflect the orientation of the regional scale structures.

The diabase is typically massive, medium to coarse grained, medium brown on weathered surface, and medium green-gray on fresh surfaces. The sills are composed of pyroxene and plagioclase with minor olivine and magnetite, are only very weakly metamorphosed, probably

representing more of a hydration reaction than a regional grade event. No accumulations of sulphide or oxide minerals are observed in any of the sills mapped. The sills vary from non- to weakly magnetic, but variations in the oxide content are too fine to be visible by casual inspection. The weakly magnetic nature and flat lying orientation of the diabase generally produces large broad magnetic highs on geophysical surveys. Veins are not observed, and no mineralization is observed in the fractures. Alteration along fractures and joints is rare, but where present, consists of chlorite generally less than 1 cm wide, rare with bleached selvages up to 0.5 cm wide.

The sills are commonly jointed, with a low joint density. Poorly to moderately well developed polygonal cracks are observed on some sills, and are interpreted to be cooling cracks on the upper surfaces of the sills. The best examples of polygonal cracks are along the logging roads south of Garden Lake.

PLEISTOCENE

The extent of glacial cover in the area is highly variable, ranging from extensive esker and moraine sediments to till and boulder till. Much of the area is covered by till and boulder till with variable amounts of sand. Thicker accumulations of till are present in the lee of some diabase sills. The mainland shore of the lakes is commonly till covered.

Three esker systems cross the Garden Lake belt trending south to southeast direction, between Ruffo and Garden Lake, west of Garden Lake, and west of Kearns Lake. The eskers appear to have been braided stream systems resulting in broad esker ridge systems. These eskers are part of major regional systems extending for tens of kilometres to the north and south (Barnett et al., 1991).

A thick moraine, the Kaiashk Interlobate Moraine, covers the eastern end of the belt resulting in a loss of bedrock exposure (Sage et al., 1973). The moraine consists of interbedded sand, silt, clay, and conglomerate horizons (Photo 10). These sediments are generally red to reddish brown, which is interpreted to be a result a high percentage of Sibley Group metasedimentary rocks as clastic material. The moraine was estimated to have a thickness of greater than 60 m by Milne (1964).

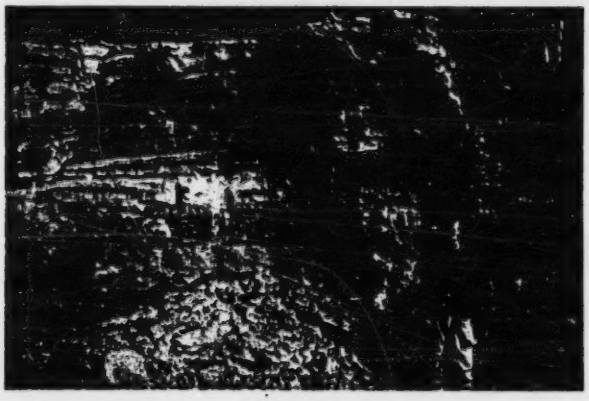


Photo 10. Well bedded clay, silt and conglomerate beds of the thick glaciofluvial moraine deposits blanketing the eastern edge of the Garden Lake Belt; located along the Kitchen Lake road.

Glacial flow directions determined from striae are oriented at 195°, similar to the long axis of the esker systems.

RECENT

Recent deposits of unconsolidated swamp, lake and stream sediments are common but of limited extent. These deposits are organic rich, and all lakes in the map area have a high tannin content. Stream sand and gravel, and beach sand, are rare and are generally a reworking of glacial deposits.

Alteration

The metavolcanic and metasedimentary rocks of the Garden Lake belt are generally weakly carbonatized, with localized areas of more intense carbonatization and/or silicification. More intense alteration is commonly associated with the highly fractured or intensely sheared units within the late structures. Intense silicification is present in originally more permeable units north of Garden Lake, associated with the sulphide mineralization. Minor epidote alteration and weak fracture related alteration is also present along the north side of the belt. A close proximity to the contact with the felsic intrusive rocks and an increase in metamorphic grade hinders the separation of the effects of metamorphism and alteration.

Incipient weak to moderate pervasive and fracture filling carbonate (calcite) alteration is common in all of the metavolcanic and metasedimentary rocks of the belt. The intensity of carbonatization may be related to the original permeability of the units, with tuffaceous units commonly displaying a higher degree of carbonatization. An example of the more intense of carbonatization observed in the mafic tuffs and flows along the west shore of Kearns Lake. A dramatic increase in the intensity of carbonatization occurs within the late structures and is most noticeable within the shears of the GLDZ, along the shore of Garden Lake. Iron carbonate becomes the dominant form of carbonate as haloes about veins and flooding of sheared units in the Agar Creek gold showing (Photo 11). The carbonatization varies from moderate to intense, and decreases in intensity over less than a metre away from the veins. The intensity of carbonate flooding associated with shearing of the metavolcanic rocks is directly related to the intensity of shearing, as observed on the islands in Garden Lake and within the trenches of the Point and Bluff gold showings. At the Bluff showing, pervasive iron carbonate flooding results in a medium to light brown for the sheared mafic metavolcanic rocks on weathered surfaces (Photo 12). Highly sheared mafic metavolcanic rocks with intense iron carbonate alteration are also present along the Kitchen Lake road, a possible extension of the GLDZ, and the Holinshead Lake road. Iron carbonate also occurs in veins, with quartz in the Agar Creek and Kearns Road gold showings. This close association between gold mineralization and iron carbonate alteration provides a useful indicator for gold mineralization in the belt (*see* "Economic Geology").

A distinctive form of carbonate alteration occurs in a fractured massive mafic flow along the stream leading into the south end of Kearns Lake. An irregular, east trending, 10 to 20 cm wide fracture is filled with iron carbonate and subhedral, dark green, actinolite. This fracture is north of the new gold showing (*see* "Occurrence - Gold - Kearns Road"), which is associated with a quartz vein containing iron carbonate. The fracture is south of the very coarse grained feldspar porphyry (*see* "Granitoid Rocks – Dykes"), indicating the proximity of the granitoid rocks. The fracture filling is interpreted to be closely related to the intrusion of the felsic intrusive rocks due to the subhedral nature of the amphibole.

Photo 11. Agar Creek Showing: brittlely fractured mafic metavolcanic rocks containing white quartz stringers, with iron carbonate alteration haloes, disseminated fine grained euhedral pyrite, and minor dark green micaeous alteration in some fractures. This alteration is very similar in appear to the veining and alteration in the Kirkland Lake area. West Shore of Garden Lake.

Photo 12. Bluff Showing: intensely sheared and very strongly iron carbonate altered mafic metavolcanic rock with disseminated very fine grained pyrite and occasional 0.5 to 3.0 cm wide bands containing 3-5% fine grained anhedral pyrite and pyrrhotite. South east shore of Garden Lake.

Silicification and quartz veining is commonly associated with shearing and fracturing in the gold showings within the GLDZ. Quartz veining is more visible than silicification due to the pervasive brown staining of the iron carbonate alteration. Some veins appear to be laminated and may be intensely deformed cherts. Others may be highly sheared and silicified with the chloritic material being highly sheared remnant of the original host rock. The silicification is commonly closely associated with the veins, and may be a flooding of the wallrock to the vein. An example of this close association is exposed in the Bluff showing, where thick laminated quartz rich bands up to a metre wide have green micaceous septa. These bands may be the product of silicification, intense shearing of chert beds, or shearing of quartz veins.

Weak silicification is observed in a number of areas and, as with carbonate alteration, appears to be more common in originally porous units. Intense strati-bound silicification is observed in two horizons interbedded with the iron formation and sulphide mineralization, north of Garden Lake. The northern horizon is a mafic tuffaceous conglomerate interbedded with the unaltered tuffaceous conglomerates, exposed along the road accessing Garden Lake. This horizon is light blue gray, very intensely silicified with some original clasts still visible in outcrop. Stratigraphically below, or north, of the iron formations and sulphide mineralization, this horizon outcrops west of the sulphide occurrences. The second horizon is a similar light blue gray, but may have been a finer clastic lithology as no primary features are visible. The second horizon is located above, or south, of the main series of eastern trenches, but below the southern trench. This style of silicification combined with the presence of chert-magnetite iron formation indicates a high volume of hydrothermal fluid passed through the rocks in this area.

Minor epidote alteration is observed in the metavolcanic rocks in the area of the Bumbu showing, north of Garden Lake. Small, 2 to 3 cm pods and lenses of light green epidote, with minor quartz, occur stratigraphically above and below the sulphide mineralization. These pods are not extensive, commonly constituting <1% of the outcrop, but they appear to be primary features. The epidote alteration is probably related to the same hydrothermal event that deposited the sulphide and iron formations.

The felsic intrusive rocks are generally unaltered with the exception of rare epidote filled fractures and epidote and/or potassium feldspar alteration along joints. Medium to dark green, very fine grained epidote occurs along some fracture and joint sets in the massive felsic intrusive rocks along the north side of the belt. The epidote-filled fractures are generally less than 1 cm wide, and may have weakly epidotized or have pink potassium feldspar margins. Potassium feldspar alteration is also observed as thin, less than 1 cm, alteration haloes about barren fractures. Minor potassium feldspar alteration was noted in the intermediate metavolcanic rocks along the southwest shore of Kearns Lake. This alteration is probably a result of the proximity of the felsic intrusive and granitoid rocks.

Chlorite alteration along fractures is common in the mafic metavolcanic rocks of the belt, but difficult to separate from the effects of regional metamorphism. North of the Bumbu showing, strongly chloritized tuff is interbedded with the tuffaceous conglomerates and closely associated with the less intensely silicified conglomerate. In most cases, chlorite is confined to late fractures, and shears. Chlorite alteration also rarely occurs in some joints in the diabase, with white, albitized margins less than 1 cm wide.

The mafic metavolcanic units along the north west margin of the belt also exhibit fine fractures with albite and quartz alteration haloes. The fractures are perpendicular to the contact with the felsic intrusive rocks, and diminish in intensity moving away from the contact (Photo 2). The alteration haloes are generally 3 to 5 mm wide, light green to gray and have a positive

weathering profile. The fractures are subparallel, and in some locations, a stockwork pattern is developed. These fractures crosscut the foliation of the units, indicating that the alteration event post-dates the peak deformation.

Garnet is a common mineral in the tuffaceous conglomerate units along the northern margin of the belt (Photo 3). These units are interbedded with the intensely silicified horizon and crosscut by the albite – quartz fractures. The garnet is generally confined to the matrix and is only observed in the altered rims of clasts in one unit. There are two possible interpretations for the garnet in the metavolcanic units. One is that these tuffaceous conglomerates have been reworked allowing a small component of sedimentary material and incipient alteration of some of the volcanic fragments. The sedimentary material and alteration could have resulted in the higher Al_2O_3 content and formation of garnet during intrusion of the felsic intrusive rocks and metamorphism. The other explanation is that that garnets are the result of alteration in a synvolcanic hydrothermal system. The presence of the iron formations and silicified clastic horizons indicates a high degree of hydrothermal alteration for some units in this area. A lack of the aluminosilicate minerals commonly associated with hydrothermal alteration favours the first interpretation.

The late gabbro intrusions along the Mooseland River have minor alteration along some fractures. Commonly the alteration is medium green serpentine in fractures less than 1 cm wide. The serpentine may have associated white quartz. There is little to no alteration of the wallrock adjacent to the fractures. Fracturing and shearing along the western side of the west intrusion results in a finer grain size and possibly alteration producing a melanocratic gabbro. In the same area, intense shearing is accompanied by quartz and epidote alteration. The massive gabbro is also weakly altered with leucoxene replacing magnetite, and limonite rimming pyrite.

Metamorphism

The metavolcanic and metasedimentary rocks of the Garden Lake belt display a variation in mineral assemblages indicating a zoning of metamorphic grade, from a central region of lower greenschist facies to marginal zones of upper greenschist to possible lower amphibolite facies. This zoning is accompanied by an increase in strain on a microscopic scale to the north and south, and on a macroscopic scale to the south and along the Garden Lake Deformation Zone.

Metasedimentary units and intermediate metavolcanic units in the central portion of the belt have a quartz-albite-sericite mineral assemblage indicative of lower greenschist facies metamorphism (Fyfe et al., 1962). The common mineral assemblage for the mafic metavolcanic rocks towards the margins is albite-chlorite-actinolite-biotite indicating a middle greenschist facies (Fyfe et al., 1962). Igneous hornblende may be present as phenocrysts, often with cleavages oriented at a high angle to the foliation, and is commonly replaced by biotite and actinolite. Biotite also occurs as the laths in the groundmass are commonly aligned with the foliation. Chlorite partially replaces biotite indicating a retrograde reaction to lower greenschist facies.

Higher metamorphic grades are attained along the margins of the belt. The tuffaceous conglomerate on the northern margin of the belt, north of Garden Lake, contains garnet and biotite in the groundmass indicating upper greenschist grade (Fyfe et al., 1962). The garnet displays internal structures indicating a rotation interpreted to indicate that upper greenschist grade was obtained prior to, and sustained during, deformation. The occurrence of fine grained, subhedral hornblende and fine laths of biotite in a highly polygonized mafic metavolcanic rock

along the southwest margin indicate a peak at upper greenschist grade. The high degree of polygonization indicates a higher and more prolonged strain event. This area has retrograded to lower to middle greenschist grade with the formation of chlorite after hornblende and biotite. The higher metamorphic grade along the margins of the belt is interpreted to be a result of the intrusion of the granitoid rocks (e.g. Blackburn et al., 1991; Jackson and Fyon, 1991).

Foliated granitoid rocks have a quartz-microcline-albite-biotite-muscovite-epidote mineral assemblage interpreted to indicate an upper greenschist facies regional metamorphism (Fyfe et al., 1962). The quartz and feldspars are polygonized, and often form elongate aggregate grains aligned along the foliation. Myrmekitic textures are more common in these units compared to the massive felsic intrusive rocks. These textures are interpreted to indicate a longer, more intense deformation history for the granitoid rocks. The gabbro bands in the gneissic granitoid rocks have subhedral hornblende and clear polygonal feldspar interpreted to have formed under amphibolite to upper greenschist facies. Garnet was not observed in thin section but was rarely observed in the field.

Massive felsic intrusive rocks have been metamorphosed to lower to middle greenschist facies with a mineral assemblage of quartz-microcline-albite-muscovite-epidote-chlorite-biotite. Hornblende is present as irregular shaped interstitial grains interpreted to be an original igneous mineral being replaced by biotite. There is little to distinguish assemblages of upper and middle greenschist facies in a quartz-feldspar dominated system, and the above assemblage could represent upper greenschist facies metamorphism. The chlorite appears to replace biotite, indicating a retrograde reaction to a lower greenschist grade. The massive felsic intrusive rocks have been strained, with the quartz and feldspar being polygonized, with the rare occurrence of myrmekite.

Lithogeochemistry

A total of 40 representative samples of metavolcanic and intrusive rocks were collected from the Garden Lake belt to aid in the identification of lithogeochemical stratigraphic trends. The majority of samples are of mafic metavolcanic rocks with a lesser number of intermediate and felsic metavolcanic rocks, with the distribution generally reflecting the abundance of each unit (Table 2). Samples were also selected to provide a series of three traverses across the belt in the areas of Kearns Lake, Garden Lake, and along the highway (Figure 3, 4a and b). The samples collected during this mapping program have been augmented by data made available by K. Tomlinson (Tomlinson et al., 1998; 1999).

Analytical work was completed at the Geoscience Laboratories of the Ministry of Northern Development and Mines. The major element analyses were completed by x-ray fluorescence using fused glass disks, and the trace elements and rare earth elements (REE) by inductively coupled plasma mass spectrometry (ICP-MS) from a closed beaker digestion. The data supplied by K. Tomlinson was analysed at the laboratories of the Geological Survey of Canada. The analytical techniques used were major elements by x-ray fluorescence using fused glass disks, select trace elements by x-ray fluorescence using press powder pellets, and the remaining trace and rare earth (RE) elements by inductively coupled plasma mass spectrometry (ICP-MS).

Table 2. Whole rock lithogeochemical analyses.

Field number	2012	202	2069	2295	2297	2302	2308	2434
Lab number	99TRH-079	99TRH-028	99TRH-020	99TRH-063	99TRH-064	99TRH-065	99TRH-071	99TRH-069
UTM east	295074	285591	285268	302365	302748	302851	309327	309536
UTM north	5491998	5487777	5487475	5495069	5494664	5494514	5489483	5492619
UTM zone	16	16	16	16	16	16	16	16
Field ID	2a	2k	2a	2a	2a	2f	2a	2k
Symbol	O	O	O	O	O	O	O	O
SiO_2	47.31	49.07	48.46	47.23	45.78	48.35	49.44	51.01
TiO_2	0.63	0.87	0.94	0.88	0.79	1.01	0.87	0.79
Al_2O_3	14.59	13.57	16.99	14.70	16.78	14.69	14.56	14.72
Fe_2O_3	12.44	11.82	12.10	13.12	12.66	13.00	13.45	12.16
*FeOT	11.19	10.64	10.89	11.81	11.39	11.70	12.10	10.94
MnO	0.19	0.26	0.23	0.28	0.23	0.30	0.22	0.19
MgO	9.77	4.24	4.49	6.93	6.96	5.51	7.56	7.14
CaO	11.45	12.60	10.45	11.57	12.65	11.41	10.26	8.08
Na_2O	1.34	2.12	1.83	1.60	2.24	2.15	2.57	3.15
K_2O	0.09	0.09	0.06	0.36	0.14	0.16	0.20	0.14
P_2O_5	0.04	0.07	0.07	0.06	0.05	0.07	0.06	0.07
LOI	2.21	5.51	4.73	3.17	1.33	3.54	0.80	2.54
Total	100.06	100.22	100.35	99.90	99.61	100.19	99.99	99.99
Mg #	0.47	0.29	0.29	0.37	0.38	0.32	0.39	0.40
Rb	1.40	1.99	0.97	3.81	0.46	0.43	3.37	2.90
Sr	71.2	219.6	137.6	159.4	98.6	89.9	60.7	247.8
Cs	0.10	0.13	0.07	0.10			0.08	0.14
La	2.00	2.89	2.75	2.96	2.40	3.54	2.81	7.04
Ce	5.13	7.50	6.92	7.34	5.80	8.06	6.79	14.51
Pr	0.83	1.20	1.10	1.22	0.96	1.38	1.10	1.88
Nd	4.30	5.79	5.26	6.37	5.15	7.39	5.88	8.15
Sm	1.41	1.80	1.64	1.93	1.50	2.29	2.04	2.18
Eu	0.49	0.70	0.69	0.67	0.57	0.74	0.64	0.65
Gd	1.72	2.18	2.00	2.43	1.80	2.62	2.28	2.57
Tb	0.30	0.37	0.36	0.46	0.34	0.50	0.43	0.44
Dy	2.24	2.46	2.34	3.13	2.18	3.38	3.14	2.96
Ho	0.46	0.55	0.53	0.69	0.45	0.74	0.66	0.65
Er	1.23	1.58	1.54	1.88	1.40	2.01	2.02	1.85
Tm	0.23	0.24	0.23	0.35	0.19	0.37	0.35	0.33
Yb	1.28	1.54	1.50	1.94	1.20	2.04	2.07	1.73
Lu	0.22	0.25	0.26	0.30	0.18	0.34	0.31	0.28
Ta	0.26	0.13	0.14	0.32	0.34	0.36	0.29	0.38
Nb	1.5	1.7	1.6	2.3	2.6	2.7	2.2	2.9
Hf	1.06	1.25	1.17	1.44	1.22	1.62	1.37	1.78
Zr	37	40	37	50	43	59	49	65
Y	13.7	15.9	14.9	17.9	9.7	19.5	20.1	18.1
Th	0.12	0.29	0.26	0.17	0.11	0.23	0.23	1.41
U	0.03	0.07	0.06	0.06	0.06	0.08	0.06	0.39
Ti/Zr	10.2	13.0	15.2	10.6	11.0	10.3	10.7	7.3
La/Yb n	1.0	1.3	1.2	1.0	1.3	1.2	0.9	2.7
Zr/Y	2.7	2.5	2.5	2.8	4.4	3.0	2.4	3.6

*FeOt - recalculated from Fe_2O_3
Mg# - cation Mg/(Fe+Mg)
n - chondrite normalized La: 0.329, Yb: 0.22; from Nakamura 1977
symbol - as used in accompanying figures

Table 2. continued

Field number	2452	28	30	484	59	72	86
Lab number	99TRH-074	99TRH-031	99TRH-032	99TRH-068	99TRH-030	99TRH-017	99TRH-016
UTM east	313880	292836	292992	309436	292090	288205	288022
UTM north	5496693	5492014	5492057	5493119	5492133	5489997	5489824
UTM zone	16	16	16	16	16	16	16
Field ID	2f	2a	2f	2a	3k	2a	2a
Symbol	O	O	O	O	O	O	O
SiO_2	47.83	49.17	47.28	48.33	62.73	48.16	48.32
TiO_2	0.71	1.03	0.73	0.79	1.42	1.17	0.81
Al_2O_3	17.22	15.30	14.88	15.38	19.04	15.71	16.49
Fe_2O_3	12.21	13.29	11.47	11.25	2.45	13.87	12.54
*FeOT	10.99	11.96	10.32	10.12	2.20	12.48	11.28
MnO	0.19	0.22	0.23	0.16	0.06	0.21	0.21
MgO	6.51	6.45	6.09	9.23	1.60	6.57	6.27
CaO	11.50	11.47	14.41	9.08	5.79	9.81	11.24
Na_2O	1.81	1.84	2.05	2.43	1.97	1.84	1.20
K_2O	0.36	0.11	0.11	0.13	1.52	0.28	0.05
P_2O_5	0.05	0.08	0.05	0.05	0.06	0.09	0.06
LOI	1.57	1.19	3.23	2.97	2.67	2.78	2.80
Total	99.96	100.15	100.53	99.80	99.31	100.49	99.99
Mg #	0.37	0.35	0.37	0.48	0.42	0.35	0.36
Rb	13.99	1.40	1.34	2.46	39.70	5.54	0.59
Sr	138.1	124.9	156.0	127.9	165.0	180.1	130.4
Cs	0.73	0.17	0.13	0.11	2.56	0.16	0.12
La	2.62	4.29	3.19	2.54	3.32	5.01	2.90
Ce	8.20	11.02	7.94	6.23	8.78	12.41	7.30
Pr	1.00	1.74	1.26	0.99	1.42	1.94	1.18
Nd	5.15	8.47	6.20	5.14	7.05	9.36	5.90
Sm	1.69	2.60	1.96	1.70	2.10	2.93	1.92
Eu	0.59	0.94	0.67	0.61	1.00	0.99	0.71
Gd	2.10	2.98	2.21	1.97	2.14	3.36	2.23
Tb	0.36	0.54	0.38	0.38	0.37	0.62	0.41
Dy	2.56	3.52	2.41	2.78	2.14	3.91	2.64
Ho	0.61	0.79	0.56	0.60	0.44	0.88	0.62
Er	1.73	2.31	1.62	1.61	1.20	2.61	1.81
Tm	0.31	0.36	0.24	0.27	0.17	0.39	0.28
Yb	1.73	2.42	1.56	1.55	1.02	2.58	1.91
Lu	0.28	0.38	0.25	0.25	0.16	0.43	0.30
Ta	0.29	0.23	0.18	0.29	0.28	0.24	0.17
Nb	2.0	3.0	2.5	1.9	3.9	3.5	2.3
Hf	1.12	1.84	1.20	1.31	2.42	1.90	1.31
Zr	42	60	39	50	77	61	41
Y	17.3	22.8	15.8	16.6	10.7	25.2	17.2
Th	0.17	0.42	0.24	0.17	0.33	0.45	0.28
U	0.04	0.10	0.06	0.05	0.11	0.11	0.06
Ti/Zr	10.1	10.3	11.2	9.5	11.1	11.5	11.9
La/Yb n	1.0	1.2	1.4	1.1	2.2	1.3	1.0
Zr/Y	2.4	2.6	2.5	3.0	7.2	2.4	2.4

Table 2. continued

Field number	2071	3054	467	78	78b	155	378
Lab number	99TRH-024	99TRH-072	99TRH-075	99TRH-019	99TRH-018	99TRH-023	99TRH-070
UTM east	280426	303405	315653	288217	288217	281478	310049
UTM north	5484652	5489531	5492013	5488417	5488417	5485253	5489907
UTM zone	16	16	16	16	16	16	16
Field ID	2a	2a	2a	2l	2a	3k	3k
Symbol	○	○	○	○	○	□	□
SiO_2	48.28	46.99	52.07	55.14	52.78	58.91	55.30
TiO_2	1.66	1.80	1.50	1.53	1.48	0.62	0.69
Al_2O_3	14.70	14.72	14.47	15.33	14.88	14.52	15.86
Fe_2O_3	15.30	16.24	9.96	7.58	8.09	5.79	6.95
*FeOT	13.77	14.61	8.96	6.82	7.28	5.21	6.25
MnO	0.20	0.24	0.24	0.18	0.27	0.16	0.15
MgO	6.02	3.97	6.73	4.91	5.00	2.65	4.34
CaO	8.96	11.20	6.47	6.10	7.60	6.85	6.30
Na_2O	3.60	2.96	3.98	5.97	3.91	3.57	4.98
K_2O	0.28	0.35	0.61	0.64	0.71	1.76	1.22
P_2O_5	0.12	0.13	0.16	0.16	0.16	0.15	0.17
LOI	0.70	0.96	3.50	1.88	4.75	4.49	2.98
Total	99.82	99.56	99.69	99.42	99.63	99.47	98.94
Mg #	0.30	0.21	0.43	0.42	0.41	0.34	0.41
Rb	3.51	5.72	10.45	22.46	28.57	56.81	29.08
Sr	110.8	73.8	93.1	98.0	132.3	510.8	242.3
Cs	0.17	0.11	0.24	0.27	0.32	1.62	0.41
La	6.44	5.99	6.51	5.37	6.83	26.16	18.07
Ce	16.92	14.90	16.00	14.42	16.88	51.84	45.36
Pr	2.63	2.43	2.57	2.41	2.75	6.18	5.38
Nd	12.50	12.25	13.10	12.02	13.44	22.45	20.64
Sm	3.84	4.25	3.92	3.81	4.22	4.29	3.82
Eu	1.34	1.15	1.30	1.20	1.44	0.98	0.94
Gd	4.52	4.86	4.53	4.30	5.10	3.50	3.16
Tb	0.73	0.88	0.79	0.76	0.89	0.53	0.49
Dy	4.65	6.29	5.69	4.94	5.43	3.20	2.90
Ho	0.99	1.43	1.20	1.13	1.24	0.68	0.57
Er	2.79	3.86	3.15	3.24	3.62	1.92	1.66
Tm	0.40	0.69	0.58	0.48	0.54	0.27	0.29
Yb	2.59	3.78	2.92	2.99	3.48	1.85	1.54
Lu	0.41	0.59	0.50	0.45	0.56	0.29	0.24
Ta	0.41	0.48	0.51	0.34	0.33	0.64	0.70
Nb	6.3	5.3	5.4	5.0	4.7	7.3	7.9
Hf	2.76	3.26	2.96	3.04	2.85	4.16	3.91
Zr	91	121	109	99	94	149	168
Y	28.1	37.7	31.5	30.6	34.5	19.9	17.9
Th	0.55	0.51	0.46	0.55	0.53	6.52	4.31
U	0.12	0.15	0.13	0.13	0.13	1.51	1.16
Ti/Zr	10.9	8.9	8.3	9.3	9.4	2.5	2.5
La/Yb n	1.7	1.1	1.5	1.2	1.3	9.5	7.8
Zr/Y	3.2	3.2	3.5	3.2	2.7	7.5	9.4

Table 2. continued

Field number	149	203	2041	387	417	420
Lab number	99TRH-022	99TRH-029	99TRH-078	99TRH-073	99TRH-067	99TRH-066
UTM east	282093	280681	285584	312073	301423	302386
UTM north	5485493	5486839	5489742	5494522	5491242	5491844
UTM zone	16	16	16	16	16	16
Field ID	2a	3k	2a	3k	2l	3k
Symbol	◊	◊	◊	◊	◊	◊
SiO_2	66.36	65.24	64.64	60.41	58.36	58.11
TiO_2	0.79	0.46	0.52	0.68	0.63	0.46
Al_2O_3	15.94	15.24	16.26	15.60	13.94	14.08
Fe_2O_3	3.99	3.25	6.23	7.52	7.00	9.97
*FeOT	3.59	2.92	5.61	6.77	6.30	8.97
MnO	0.07	0.13	0.09	0.25	0.15	0.35
MgO	1.14	0.60	1.03	3.05	4.62	1.63
CaO	3.14	4.05	3.24	2.55	4.57	4.22
Na_2O	5.56	2.92	3.91	3.15	3.37	2.37
K_2O	1.21	2.71	1.39	3.16	0.88	1.72
P_2O_5	0.24	0.18	0.11	0.25	0.14	0.22
LOI	0.82	4.71	1.39	2.76	5.94	6.16
Total	99.26	99.49	98.81	99.38	99.60	99.29
Mg #	0.24	0.17	0.16	0.31	0.42	0.15
Rb	39.13	73.95	31.58	55.42	26.47	40.50
Sr	329.6	228.1	391.3	465.8	187.8	384.3
Cs	1.42	1.63	1.29	1.74	0.59	0.73
La	33.70	36.59	23.38	33.90	21.43	58.24
Ce	67.67	72.61	47.45	73.95	44.68	124.28
Pr	8.04	8.80	5.10	7.78	4.76	13.72
Nd	28.43	31.73	19.78	29.70	17.34	49.01
Sm	4.83	5.04	3.03	4.86	3.26	6.54
Eu	1.24	1.33	0.85	1.19	0.81	1.44
Gd	3.76	3.22	2.43	3.68	2.81	4.62
Tb	0.56	0.42	0.33	0.51	0.42	0.58
Dy	3.37	2.48	1.62	2.57	2.56	2.23
Ho	0.67	0.46	0.32	0.50	0.53	0.40
Er	1.85	1.30	0.82	1.46	1.45	1.06
Tm	0.26	0.17	0.14	0.28	0.24	0.18
Yb	1.67	1.24	0.88	1.38	1.26	1.06
Lu	0.26	0.19	0.13	0.25	0.21	0.17
Ta	0.71	0.52	0.44	0.72	0.65	0.75
Nb	10.5	5.8	3.6	7.3	7.2	6.5
Hf	4.87	3.64	2.74	3.85	3.48	3.59
Zr	186	127	109	164	147	154
Y	18.6	13.4	9.2	15.9	15.4	11.1
Th	5.76	8.40	2.95	7.40	3.82	8.91
U	1.05	1.59	0.92	1.63	0.77	2.58
Ti/Zr	2.5	2.2	2.9	2.5	2.6	1.8
La/Yb n	13.5	19.7	17.8	16.4	11.4	36.7
Zr/Y	10.0	9.5	11.8	10.3	9.5	13.9

Table 2. continued

Field number	1004	348	149b	150	2078	2	243
Lab number	99TRH-076	99TRH-077	99TRH-021	99TRH-026	99TRH-025	99TRH-033	99TRH-027
UTM east	295209	293215	282093	281998	279609	292764	279163
UTM north	5490044	5488949	5485493	5485388	5484444	5491300	5489126
UTM zone	16	16	16	16	16	16	16
Field ID	3a	4a	3k	4k	2a	10d	8t
Symbol	△	△	▲	▲	▲	▼	▼
SiO_2	63.00	74.46	73.56	74.29	81.75	70.89	76.62
TiO_2	0.20	0.16	0.06	0.04	0.15	0.23	0.15
Al_2O_3	10.96	12.37	14.59	15.16	9.00	13.84	13.17
Fe_2O_3	1.49	1.40	1.09	0.70	0.65	2.14	0.60
*FeOT	1.34	1.26	0.98	0.63	0.58	1.93	0.54
MnO	0.10	0.03	0.02	0.02	0.02	0.04	0.02
MgO	0.85	0.62	0.61	0.21	0.13	0.71	0.50
CaO	8.32	1.08	1.82	1.56	0.33	2.03	0.96
Na_2O	4.20	3.74	5.36	3.96	2.43	3.59	3.55
K_2O	1.19	2.93	0.90	2.10	3.86	4.08	2.67
P_2O_5	0.04	0.03	0.03	0.02	0.03	0.08	0.02
LOI	8.38	2.19	0.94	1.05	0.65	1.49	1.57
Total	98.73	99.01	98.98	99.11	99.00	99.12	99.83
Mg #	0.39	0.33	0.38	0.25	0.18	0.27	0.48
Rb	34.34	76.08	16.50	42.03	69.90	130.06	60.78
Sr	280.1	210.4	234.2	174.4	73.1	374.3	72.9
Cs	0.74	1.70	0.34	0.17	0.54	2.92	0.36
La	50.22	14.90	8.03	5.62	41.02	48.22	27.98
Ce	99.92	29.75	17.81	17.81	85.90	89.92	60.94
Pr	9.64	2.85	2.26	2.07	11.02	9.97	6.26
Nd	32.61	10.28	8.12	7.33	42.68	32.52	20.23
Sm	4.21	1.72	2.11	2.16	9.58	4.49	3.40
Eu	0.94	0.45	0.34	0.22	1.03	0.86	0.54
Gd	3.21	1.30	1.74	1.91	8.95	2.58	2.34
Tb	0.47	0.19	0.27	0.35	1.54	0.35	0.37
Dy	2.20	0.98	1.57	2.22	9.17	2.16	2.27
Ho	0.41	0.20	0.32	0.48	1.94	0.41	0.46
Er	1.13	0.54	0.88	1.40	5.41	1.28	1.40
Tm	0.21	0.11	0.14	0.20	0.78	0.18	0.22
Yb	1.22	0.73	0.90	1.30	4.94	1.17	1.39
Lu	0.19	0.11	0.15	0.20	0.77	0.20	0.22
Ta	0.79	0.60	0.67	1.15	1.02	0.82	1.06
Nb	7.2	4.4	6.1	9.6	13.9	7.3	9.4
Hf	3.58	2.16	2.35	2.52	6.30	3.58	3.44
Zr	145	77	38	40	169	114	95
Y	14.0	6.6	9.5	12.5	47.4	12.6	15.2
Th	11.15	7.15	4.59	4.69	8.40	21.46	16.66
U	2.51	2.03	1.76	3.21	2.34	3.32	3.54
Ti/Zr	0.8	1.2	0.9	0.6	0.5	1.2	0.9
La/Yb n	27.5	13.6	6.0	2.9	5.6	27.6	13.5
Zr/Y	10.4	11.7	4.0	3.2	3.6	9.0	6.3

Table 2. continued

Field number	336	2579	439	444	474
Lab number	99TRH-080	99TRH-083	99TRH-081	99TRH-084	99TRH-082
UTM east	289882	312463	311808	290769	315182
UTM north	5487302	5492463	5491936	5487595	5492528
UTM zone	16	16	16	16	16
Field ID	10t	9c	9f	9f	9c
Symbol	▼	●	●	●	●
SiO_2	70.98	47.42	44.29	48.26	46.92
TiO_2	0.40	0.86	2.14	0.34	0.52
Al_2O_3	14.10	15.22	15.46	4.14	14.31
Fe_2O_3	2.64	11.24	16.92	10.33	8.92
*FeOT	2.38	10.11	15.22	9.29	8.03
MnO	0.03	0.16	0.19	0.18	0.16
MgO	0.92	8.75	5.50	18.85	9.55
CaO	1.39	10.24	9.63	15.80	15.80
Na_2O	4.27	2.17	2.62	0.42	0.95
K_2O	1.42	0.06	0.04	0.15	0.14
P_2O_5	0.09	0.09	0.04	0.04	0.03
LOI	2.42	3.30	2.73	2.04	2.41
Total	98.66	99.51	99.56	100.55	99.71
Mg #	0.28	0.46	0.27	0.67	0.54
Rb	37.39	0.84	0.52	2.51	3.62
Sr	95.4	168.5	126.0	87.3	126.3
Cs	0.50	0.09	0.16	0.05	0.12
La	37.81	4.89	2.57	6.29	2.19
Ce	83.68	11.54	6.15	15.30	5.31
Pr	8.44	1.81	0.97	2.35	0.89
Nd	30.88	9.41	5.30	11.71	4.82
Sm	5.26	2.97	1.66	3.01	1.72
Eu	1.06	0.94	0.75	0.75	0.62
Gd	4.12	3.38	2.09	2.91	1.96
Tb	0.58	0.62	0.37	0.40	0.37
Dy	3.10	4.50	2.76	2.37	2.69
Ho	0.59	0.98	0.56	0.44	0.58
Er	1.77	2.60	1.60	1.18	1.58
Tm	0.31	0.47	0.29	0.19	0.27
Yb	1.90	2.47	1.66	0.95	1.42
Lu	0.30	0.43	0.26	0.14	0.27
Ta	0.90	0.42	0.36	0.30	0.32
Nb	10.4	3.3	2.0	1.1	1.5
Hf	5.93	1.92	1.04	1.09	0.96
Zr	244	67	38	36	32
Y	18.0	27.3	17.6	11.3	15.1
Th	7.39	0.30	0.17	0.50	0.12
U	1.32	0.11	0.05	0.19	0.03
Ti/Zr	1.0	7.7	33.8	5.7	9.7
La/Yb n	13.3	1.3	1.0	4.4	1.0
Zr/Y	13.6	2.5	2.2	3.2	2.1

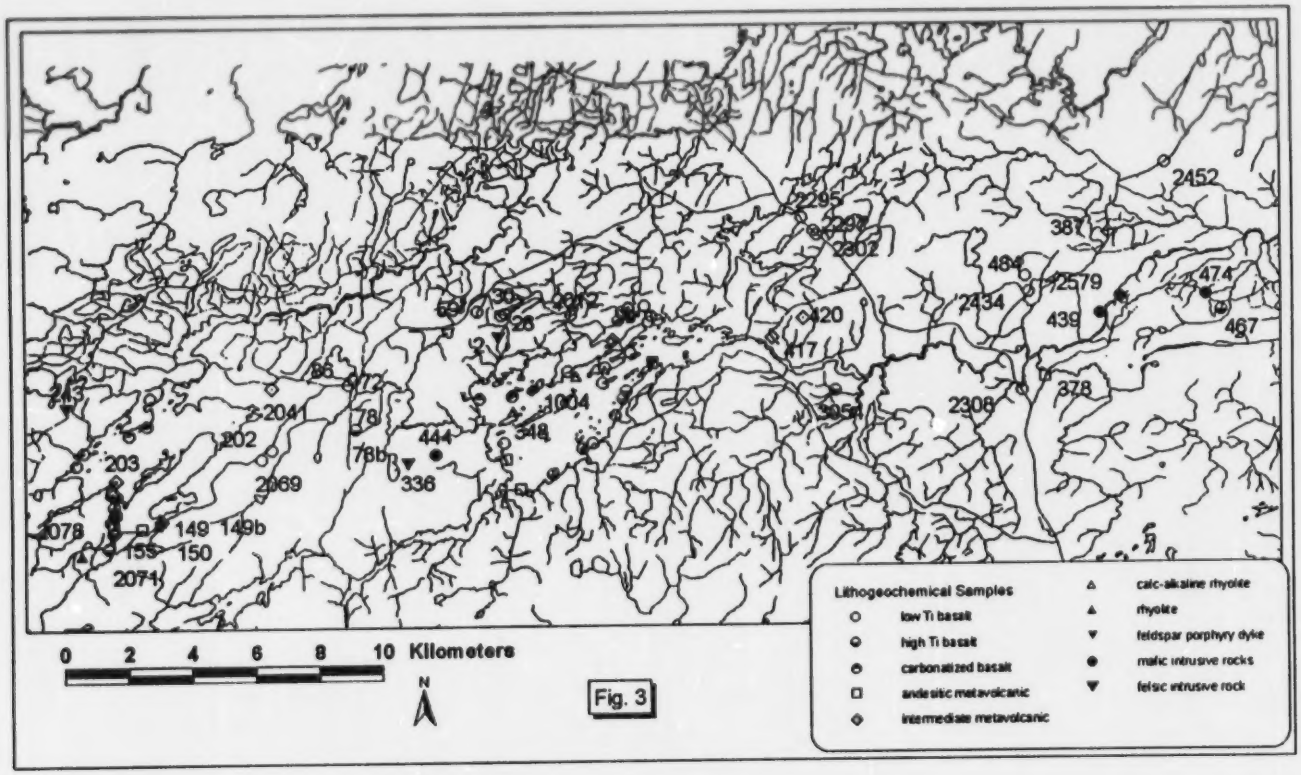
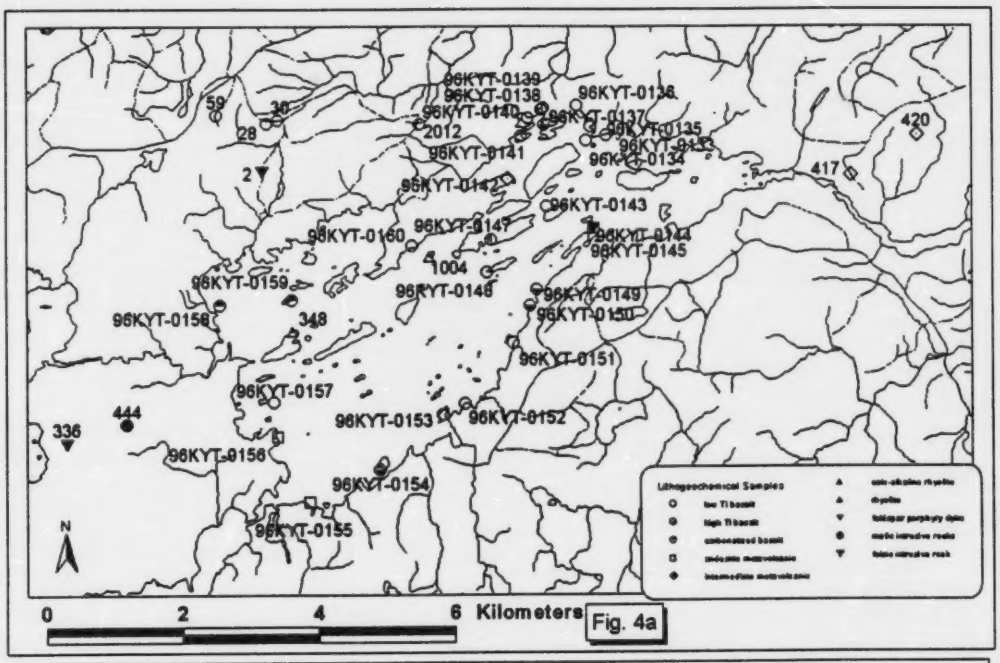


Figure 3. Location of lithogeochemical samples collected during this mapping program, with unlabeled samples from Tomlinson et al. (1998).



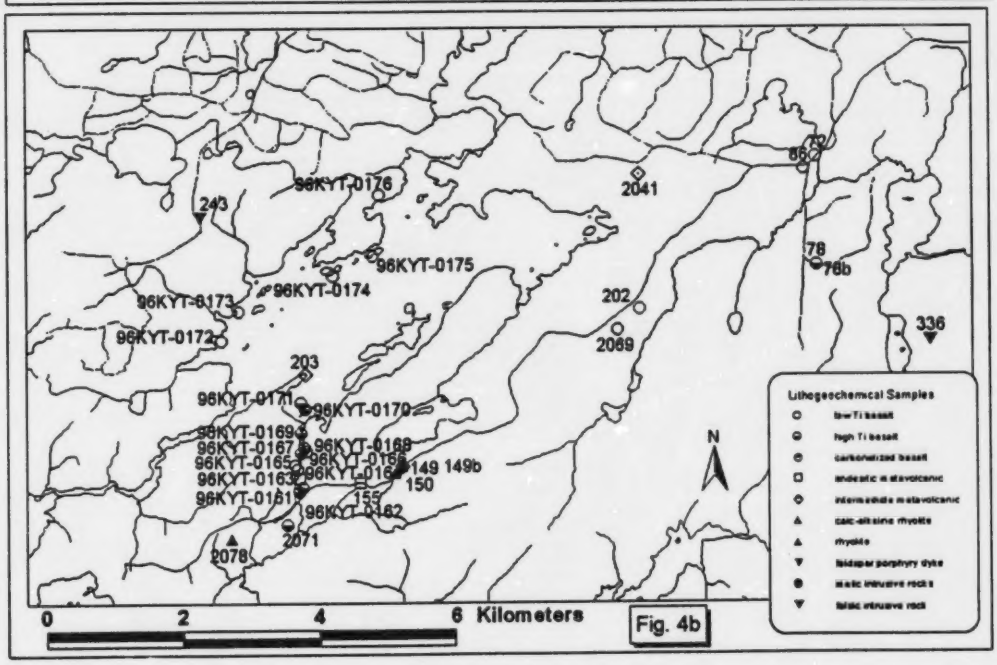


Figure 4a. Detailed location of lithogeochemical samples in the Garden Lake area, with samples prefixed 99KYT from Tomlinson et al. (1998).

Figure 4b. Detailed location of lithogeochemical samples in the Kearns Lake area, with samples prefixed 99KYT from Tomlinson et al. (1998).

MAFIC METAVOLCANIC ROCKS

A total of 19 samples of the mafic metavolcanic rocks were collected during the current mapping program (Table 2). These samples include a variety of units ranging from massive or pillowed flows to tuffs and lapilli tuffs, with varying degrees of metamorphism.

The mafic metavolcanic rocks can be subdivided into four groups based on their major and trace element abundances (Figure 5a, b, 6a). Three of the groups, representing the majority of samples, have basalt/andesite characteristics in Figure 5a. These basalt samples are subdivided into 1) low TiO_2 basalts with high Mg tholeiite characteristics, 2) high TiO_2 basalts with high Fe tholeiite characteristics on a Jensen cation plot (Figure 5b), and carbonatized basalts (Table 2). A tholeiitic character for the high and low Ti basalts is evident from the trace element and REE ratios (Figure 6b and 7a) clearly distinguishing these basalts from the other mafic metavolcanic units in the belt. The carbonatized basalt group consists of two samples located on the western end of Garden Lake (Figure 4). These samples have some similarities with the low Ti basalts, plotting as high Mg tholeiites in (Figure 5a and b), but are distinguishes by higher CaO contents and elemental ratios (Figure 6a, b, and 7a). The fourth group, or andesites, has major and trace element abundances characteristic of andesites to dacites (Figure 5a and b), but are distinguished from the intermediate metavolcanic rocks by slightly lower elemental ratios (Figure 6b and 7a).

Low Ti basalts have lower trace element and REE abundances than the high Ti basalts (Figure 6a, b, and 7a). These samples have weak negative to weak positive Eu anomalies indicative of minor plagioclase fractionation and the plagioclase porphyritic textures respectively (Figure 7b). This group also has small negative Nb and Ta anomalies, and Th below the general trend. Geographically, the low Ti basalts are predominant in the north portion of the belt, north of the central metasedimentary band (Figure 3).

High Ti basalts have higher elemental abundances but similar elemental ratios compared to the low Ti basalts (Figure 6a, b and 7a). The high Ti basalts have small negative Nb anomalies but no Ta anomalies, and Th displays either positive or negative anomalies (Figure 8a). The explanation for the Th variation is not known, as it is not related to geographical location or to the analytical laboratory. A number of amphibole rich flows are interbedded with the pillowed and massive mafic flows. These amphibolite rich units do not have a unique lithogeochemical signature, favouring formation as a result of regional metamorphism rather than a different igneous source. Geographically, the high Ti basalts are most prominent along the south side of the belt interbedded with minor low Ti basalts, south of the central metasedimentary band (Figure 3). The interbedded low Ti basalts are chemically indistinguishable from the low Ti basalts in the north portion of the belt.

The two samples in the carbonatized basalt group have higher CaO contents, and are described as fine grained, schistose, carbonate altered mafic metavolcanic rocks (Tomlinson, personal communication). These samples are located within shears of the GLDZ, and have a calcite alteration rather than the iron carbonate alteration commonly associated with the deformation zone. Both samples have steeper extended element trends with negative Nb and Ta anomalies (Figure 9a). Carbonate has been identified as a complexing agent capable of transporting the light rare earth elements (LREE), and the higher La/Yb normalized ratios could be a result of alteration (Lottermoser, 1992). The mobility of Y in a carbonate rich fluid is not known, but work in VMS hydrothermal systems indicate that Y is mobile along with the LREE (Campbell et al., 1984). Alteration could also account for the higher Zr/Y ratios. An alternate interpretation that this lithogeochemistry is primary, and these samples are related to the andesites, can not be discounted.

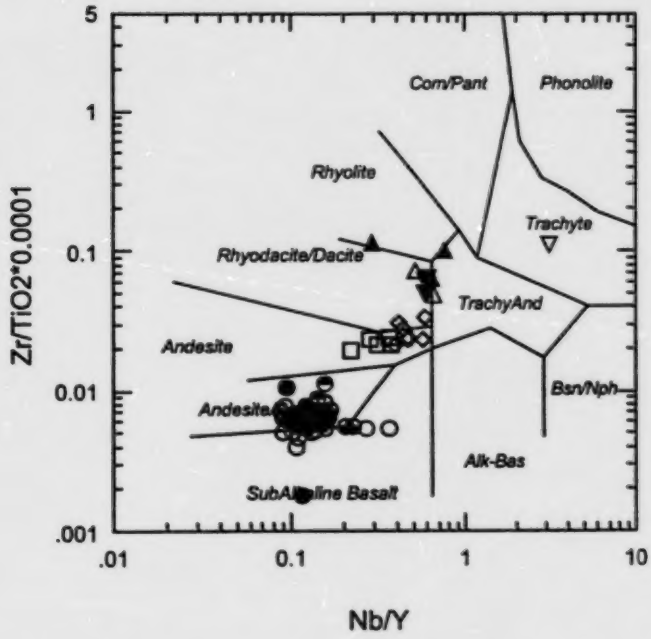


Figure 5a. Zr/TiO_2 – Nb/Y diagram of the metavolcanic and intrusive rocks (after Winchester and Floyd, 1977).

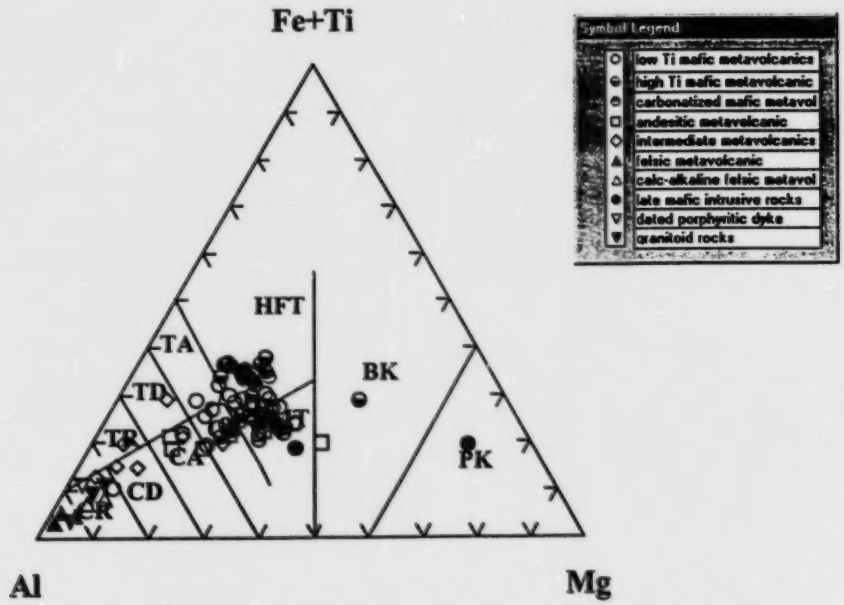
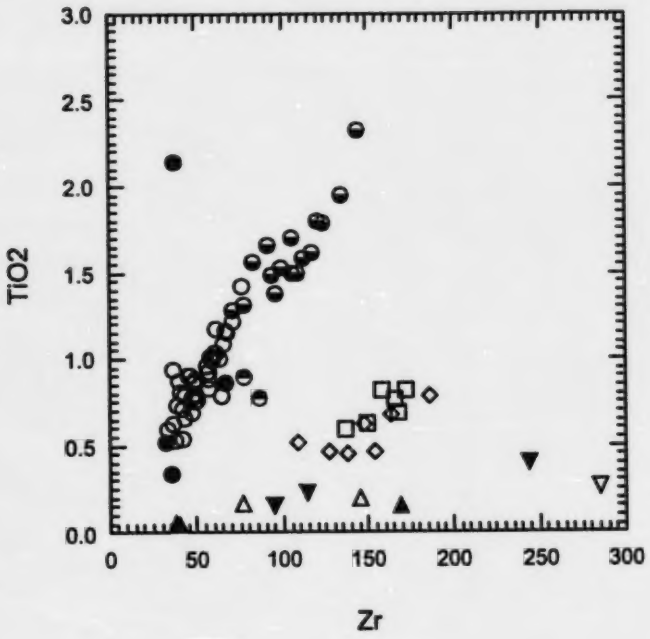


Figure 5b. Al - Fe+Ti - Mg cation ternary diagram of the metavolcanic and intrusive rocks (after Jensen, 1976).



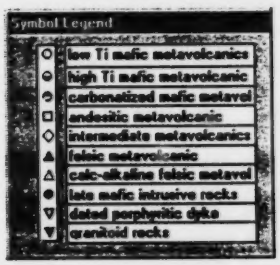


Figure 6a. TiO_2 – Zr diagram of the metavolcanic and intrusive rocks.

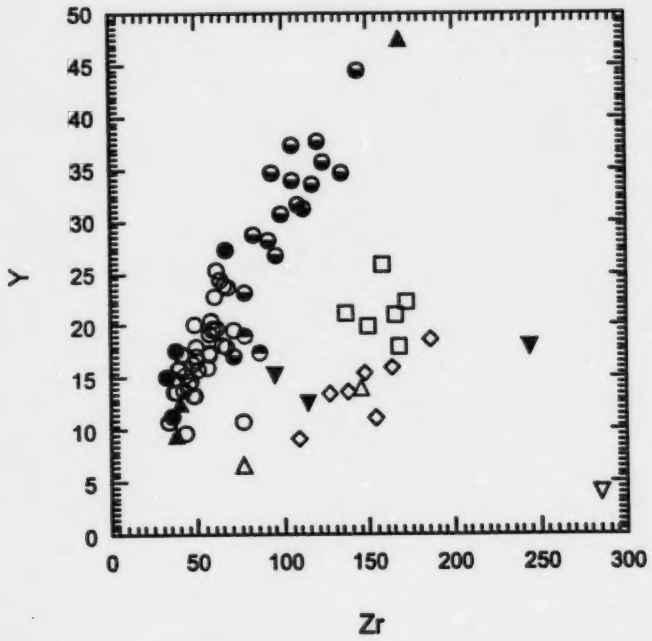


Figure 6b. Y – Zr diagram of the metavolcanic and intrusive rocks.

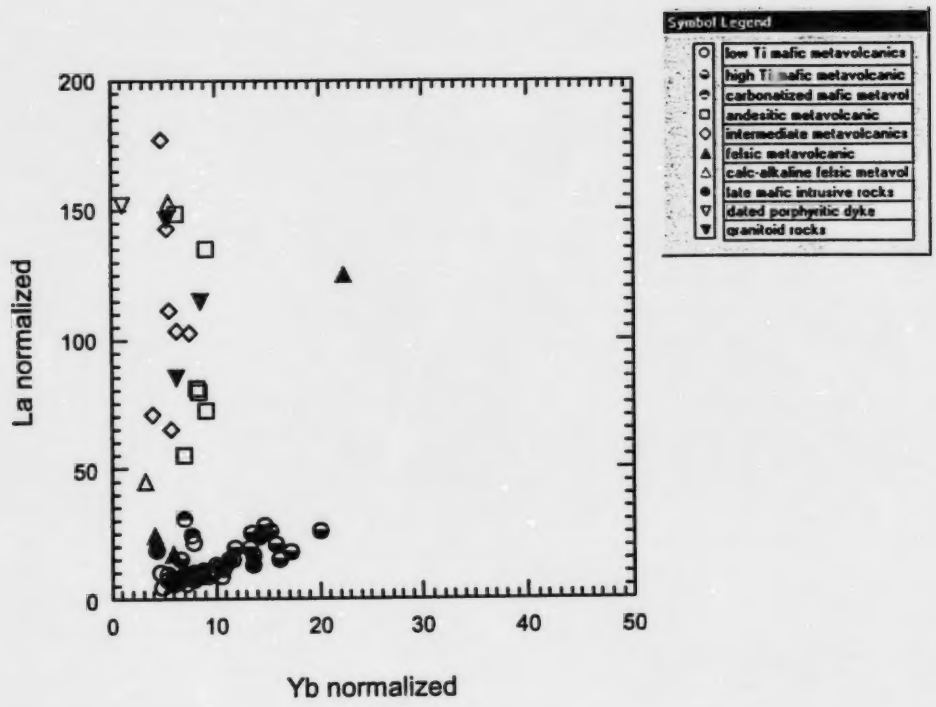


Figure 7a. La – Yb chondrite normalized of the metavolcanic and intrusive rocks (using the chondrite values of Nakamura, 1977).

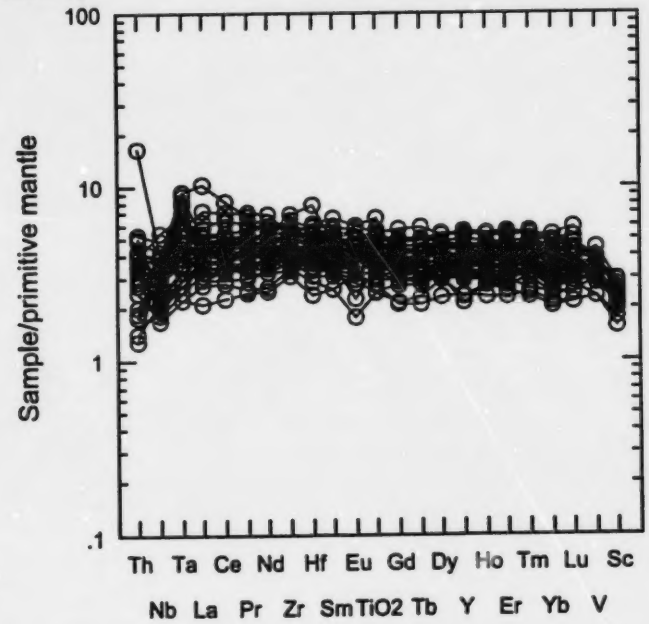


Figure 7b. Mantle normalized extended element diagram of the low TiO_2 mafic metavolcanic rocks (after Wyman and Kerrich, 1997).

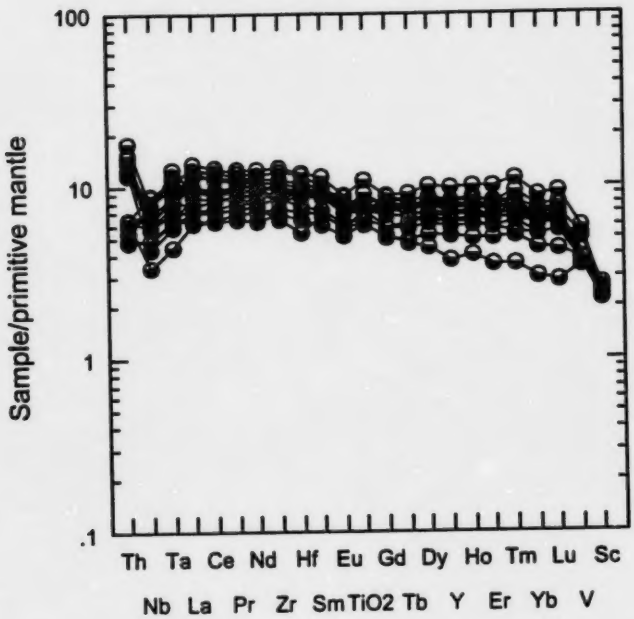


Figure 8a. Mantle normalized extended element diagram of the high TiO_2 mafic metavolcanic rocks (after Wyman and Kerrich, 1997).

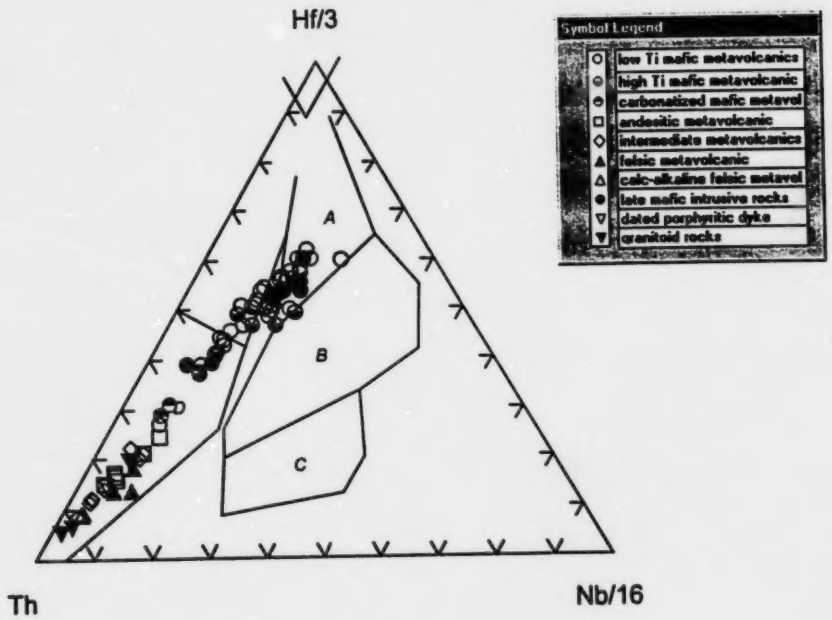


Figure 8b. Th – Hf/3 – Nb/16 diagram of the metavolcanic and intrusive rocks, A- normal midocean ridge basalts (MORB); B – enriched-MORB and tholeiitic within plate basalt (WPB) and differentiates; C – Alkaline WPB and WPB and differentiates; D – Destructive plate margins and differentiates (after Wood, 1980).

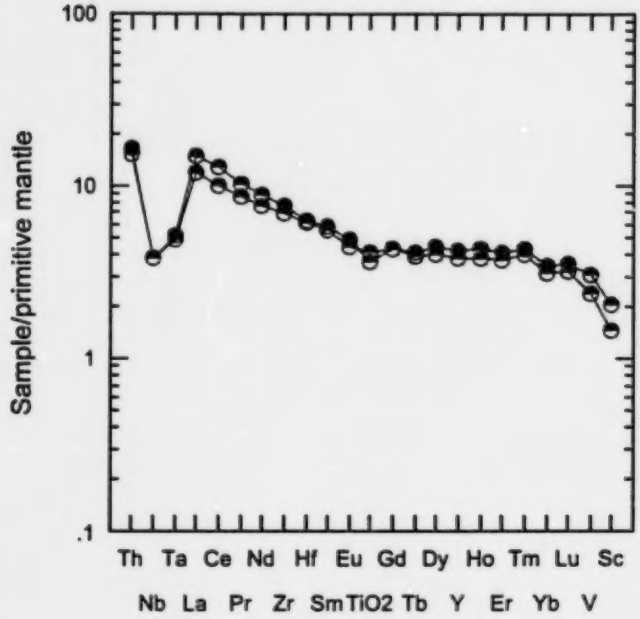


Figure 9a. Mantle normalized extended element diagram of the carbonate altered mafic metavolcanic rocks, with the field for the high TiO_2 mafic metavolcanic rocks (after Wyman and Kerrich, 1997).

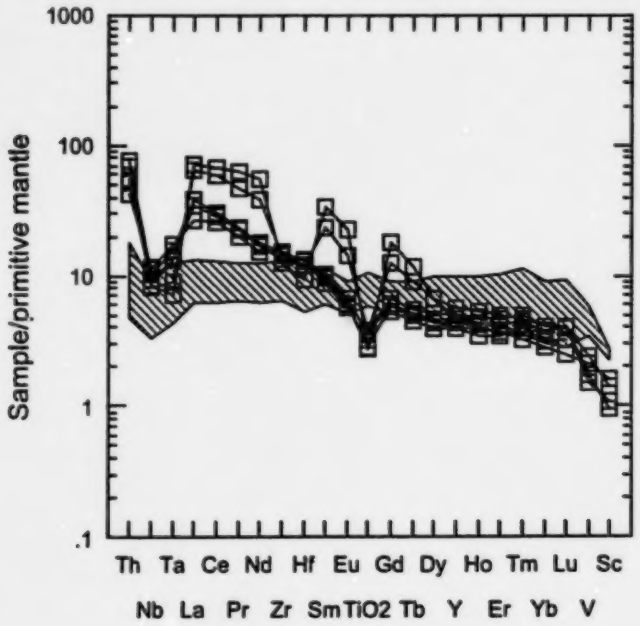


Figure 9b. Mantle normalized extended element diagram of the andesitic metavolcanic rocks, with the field for the high TiO_2 mafic metavolcanic rocks (after Wyman and Kerrich, 1997).

The andesite group has higher elemental ratios than the mafic metavolcanic units in the belt. This difference in the ratios is a reflection of lower Y and Yb and higher La abundances (Figure 6a, 7a, 10a). This group is generally restricted to the southern portion of the belt, south of the metasediments, interbedded with the high Ti basalts (Figure 3). These units are often indistinguishable from the intermediate metavolcanic rocks in the field, and this lithogeochemical subdivision may be somewhat arbitrary.

Basalts with low, tholeiitic, elemental ratios, and flat trends on extended element diagrams with negative Nb and Ta anomalies, are usually interpreted to have formed in a primitive island arc or back arc tectonic environment (e.g. Pearce, 1982). These rocks straddle the normal mid-ocean ridge (NMORB) and primitive island arc fields, trending towards the more calc-alkaline compositions in Figure 8b (Wood, 1980). The similarities in elemental ratios for the high and low Ti basalts are interpreted to indicate formation in similar tectonic environments, with the low Ti basalts being the more primitive end member. It is possible that the two basalt types are genetically related, although the current proximity may be due to tectonic emplacement. The predominance of the primitive low Ti basalts in the northern portion of the belt, with high Nd isotopic values (Tomlinson, *in press*), is interpreted to indicate that this part of the belt formed in a back arc tectonic environment with little crustal contamination. Higher elemental ratios for the high Ti basalts and andesites, larger negative Nb and Ta anomalies, and low Nd isotopic values (Tomlinson, *in press*) are indicative of a more evolved island arc volcanics with a felsic crustal component (Figure 8b).

INTERMEDIATE METAVOLCANIC ROCKS

The intermediate metavolcanic rocks were distinguished in the field based on their colour index, and often included primary and secondary reworked fragmental units. The colour distinction does not always correlate with classification based on thin sections or lithogeochemistry. This lithogeochemical subdivision is generally internally consistent, and variations and overlap with the calc-alkaline mafic metavolcanics are interpreted to be a result of a high mafic metavolcanic component in these predominantly fragmental rocks. A total of seven samples of intermediate metavolcanic rocks were analysed.

Samples of the intermediate metavolcanic rocks have major and trace element characteristics that are andesitic to dacitic (Figure 5a and b; Table 2). These samples commonly have minor amounts of quartz, visible in thin section, reflected in the generally higher SiO_2 contents. The intermediate metavolcanic rocks are generally distinguished from the felsic and calc-alkaline mafic metavolcanic rocks based on of their higher elemental ratios (Figure 6a, b, 7a, 10a). High Zr/Y and La/Yb normalized ratios are also features commonly observed in sedimentary units, and samples 2041, 420, and 387 are medium to coarse fragmental units, and in one case a tuffaceous conglomerate / debris flow (sample 2041).

The intermediate metavolcanic rocks have a calc-alkaline affinity based on the high element ratios (e.g. Figure 8b), similar to the andesite end member of the mafic metavolcanic rocks. The higher elemental ratios are interpreted to be a result of the fragmental origin and mixed mafic and intermediate clast and matrix compositions. These rocks are most closely related to the andesites, but it is not evident whether this is a genetic connection. The calc-alkaline character and the negative Nb and Ta anomalies for these units are indicative of an island arc environment (Figure 8b and 9b).

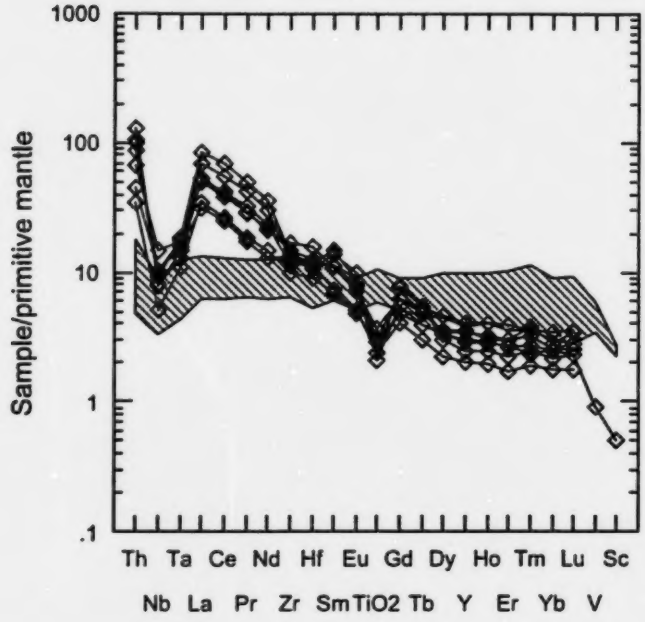


Figure 10a. Mantle normalized extended element diagram of the intermediate metavolcanic rocks, with the range for the high TiO_2 mafic metavolcanic rocks (after Wyman and Kerrich, 1997).

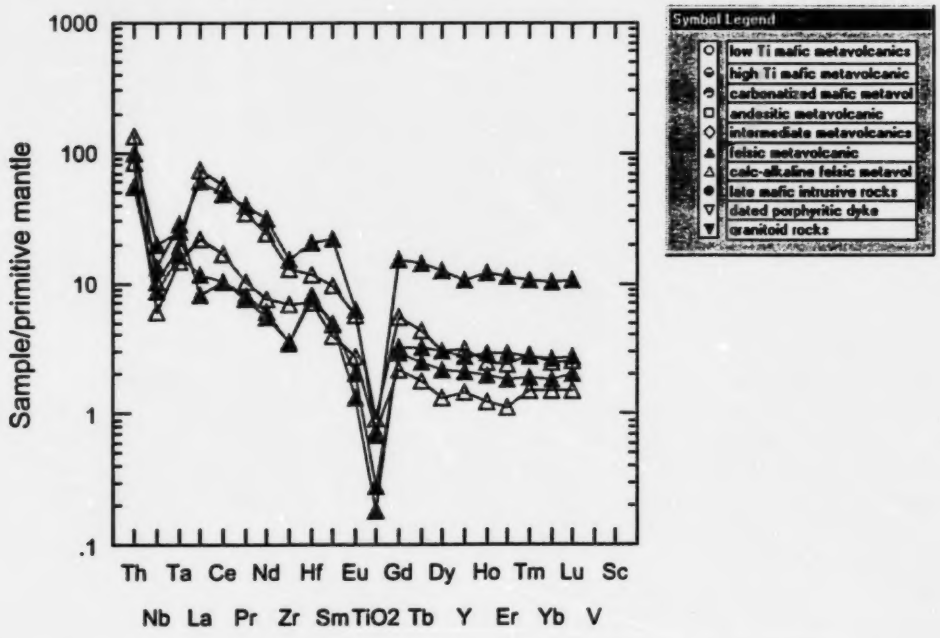


Figure 10b. Mantle normalized extended element diagram of the felsic metavolcanic rocks (after Wyman and Kerrich, 1997).

FELSIC METAVOLCANIC ROCKS

Five samples of felsic metavolcanic rocks were collected, three of the samples are from the area along the southwest margin of the belt, and two are from the central metasedimentary band (Figure 3; Table 2). Sample 2078 is from the thick series of felsic tuffs south of Kearns Lake, and samples 149 and 150 are two thin units described in the field as cherty in character. Samples 348 and 1004 are altered sericite schists located along the south side of the central metasedimentary band, on islands in Garden Lake.

A sample of the felsic tuffs located south of Kearns Lake is silicified with a SiO_2 content of 81.75% and a Al_2O_3 content of 9.00%. These major element values indicate that the abundances of the other elements have been diluted, but that ratios should not have changed. This sample has the characteristics of a rhyolite to rhyodacite (Figure 5a), and tholeiitic to transitional element ratios (Figure 6b, 7a, 10b). These ratios indicate that the samples could be classified as a FII or FIIIa felsic metavolcanic rock (Lesher et al., 1986), indicative of a potential to host VMS mineralization.

Units described as cherty felsic metavolcanic rocks are located southeast of Kearns Lake, and have SiO_2 and Al_2O_3 contents in the rhyolite range. These samples plot within the rhyodacite – dacite field in Figure 5a. Trace element abundances are low, in the same range as the basalts, but the element ratios are comparable to the felsic tuff (Figure 6b, 7a, 10b). The ratios suggest an FII or FIIIa classification, but the low element abundances means that these samples fall outside of this classification scheme. This mixture of low trace element abundances and low ratios with rhyolitic major element abundances is difficult to interpret and could be a result of a reworked tuffaceous origin or a chert with a high tuffaceous component.

Samples 348 and 1004 plot within the rhyodacite – dacite field in Figure 5a, but sample 1004 has a low SiO_2 and Al_2O_3, and high CaO and LOI values as a result of carbonatization. These samples have low elemental abundances, in the same range as the basalts, but have trace element ratios comparable to the calc-alkaline andesites (Figure 6a, b, 7a, 10b). As with the thin cherty units, this mixture of element abundances and ratios is difficult to interpret. There is the possibility that these samples are metasedimentary in origin, but higher Al_2O_3 contents would be more common in metasediments (Table 2). Samples 348 and 1004 are interpreted to be calc-alkaline tuffs, with the element abundances being affected by reworking.

The felsic metavolcanic rocks are divided into two distinctive groups based on lithogeochemistry and geography. The southern felsic tuff and cherty felsic metavolcanic rocks have FII – FIIIa characteristics with negative Nb and Ta anomalies indicative of an island arc environment (Figure 8b and 10b). The felsic metavolcanic rocks in the central metasedimentary band are calc-alkaline with a possible re-worked sedimentary component. Both rock types are thin tuffaceous units probably deposited distally. The back arc to immature – primitive arc lithogeochemical signature of the mafic metavolcanic rocks would be compatible with evolution of this belt at some distance from the main arc and the larger felsic volcanic centres.

Due to the higher degree of deformation along the south margin of the belt, and the presence of felsic intrusive dykes, there is the potential for mis-identification of the felsic metavolcanic units in these areas. Comparison to the element ratios of the felsic metavolcanic rocks easily distinguishes these units from the granitoid rocks (Figure 6b, 7a, 11a). The lithogeochemistry could be used for verifying field identifications in the areas of higher deformation.

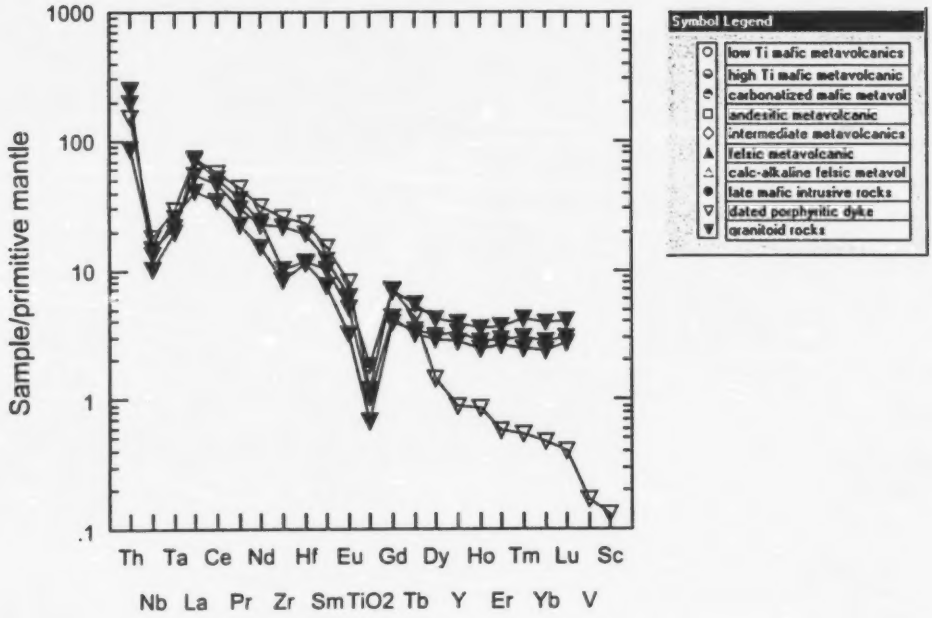


Figure 11a. Mantle normalized extended element diagram of the felsic intrusive rocks and feldspar porphyry dyke (after Wyman and Kerrich, 1997).

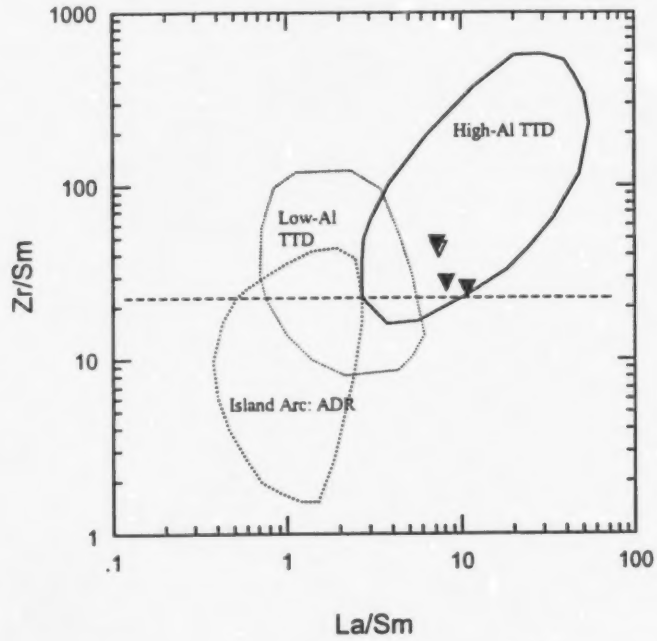


Figure 11b. Zr/Sm – La/Sm diagram of the felsic intrusive rocks (after Fen et al., 1998).

FELSIC INTRUSIVE AND GRANITOID ROCKS

Three samples of the late felsic intrusive rocks were analysed, a massive felsic intrusive rocks north of Garden Lake (sample 2), a quartz-feldspar porphyritic dyke west of Garden Lake (sample 336), and a quartz porphyry dyke located west of Kearns Lake (sample 243; Table 2). These samples are augmented by a feldspar porphyritic dyke from the eastern trench of the Point showing sampled by Tomlinson et al. (1998). Sampling of the felsic intrusive rocks was only intended to provide a base line for the interpretation of the felsic metavolcanic rocks in the belt (as discussed above).

The three felsic intrusive rocks have major, trace and RE element abundances and ratios that are generally comparable (Figure 5a, 6a, b, 7a, and 11a). The most noticeable difference is the higher Zr content of the quartz-feldspar porphyritic dyke, and the lower Zr content of the quartz porphyry dyke compared to the massive intrusive sample. All three samples have trace element abundances, and La/Yb normalized and Zr/Y ratios similar to the calc-alkaline felsic and intermediate metavolcanic rocks of the belt. This lithogeochemistry would not distinguish sheared dykes from the calc-alkaline felsic metavolcanic rocks of the central metasedimentary band, but these units were not observed elsewhere in the belt. This similarity in chemistry is interpreted to be a result of formation under similar igneous conditions rather than a direct genetic relationship.

Feldspar porphyritic dyke, sample 96KYT-0144, has major element abundances that are comparable to the massive intrusive and quartz-feldspar porphyry dyke samples (Table 2). The trace element and REE abundances are quite distinctive with high Zr and La abundances, and very high Zr/Y and La/Yb normalized ratios (Figure 6a, b, 7a, and 11a). The low Y abundance results in this samples plotting in the trachytic field on a Zr/TiO_2 – Nb/Y diagram (Figure 5a). The dyke intruded after the main deformation event, and is probably not related to the metavolcanic rocks of the belt (*see* "Structure").

The felsic intrusive and granitoid rocks are comparable to the tonalitic compositions reported by Fan et al. (1998) for the granitoids of the Red Lake area. The Garden Lake samples, including the feldspar porphyry, plot in the high-Al TTD field on the variation diagrams used by Fen et al. (1998; e.g. Fig 11b). The interpretation was that the tonalites formed by melting of subducted oceanic basalt crust. The elemental abundances in the felsic intrusive rocks are compatible with formation by fractionation of garnet +/- hornblende, and minor sphene / titanite to account for the high La/Yb ratios with negative Nb and Ta anomalies. These samples do not have the high Mg, Ba, Sr of the sanukitoid suite of rocks (e.g. RRC; Stern and Hanson, 1991; Stern et al., 1989), but the feldspar porphyry does have an extremely high La/Yb ratio.

MAFIC TO ULTRAMAFIC INTRUSIVE ROCKS

Gabbro

Three samples of the late mafic intrusions were analysed for majors and trace elements, and REE (Table 2). The samples were a massive gabbro from west of the river (sample 439), a massive gabbro from east of the river (sample 2579), and the eastern layered unit (sample 474). Primary mineralogical was replaced by secondary amphibole and metamorphosed feldspar, obscuring the original mineral compositions. The elemental variations are interpreted to indicate a mixing of orthopyroxene and plagioclase, with minor olivine (Figure 12a and b). The layered sample displays a slightly higher CaO contents, possibly a result of a greater clinopyroxene abundance. Trace element abundances are comparable to the main group of basalts for the Garden Lake belt

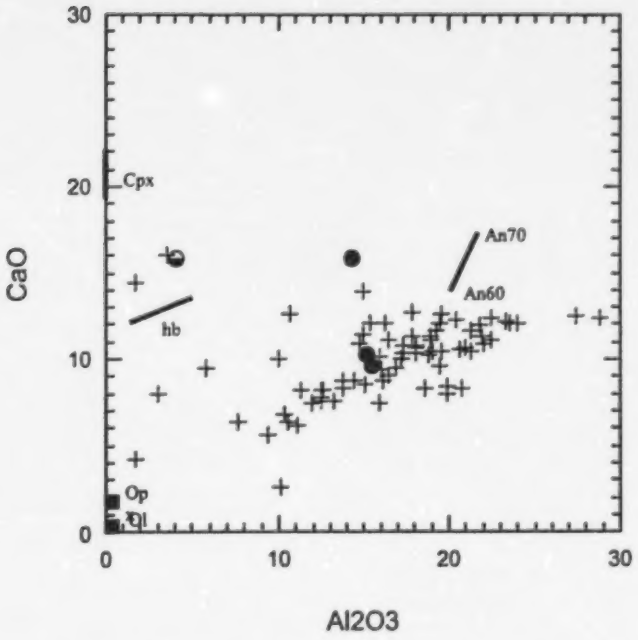


Figure 12a. CaO – Al_2O_3 for the gabbro and pyroxenite intrusions with samples from Lac des Iles as crosses (Ontario Geological Survey, unpublished data, 1999; after Sutcliffe et al., 1989).

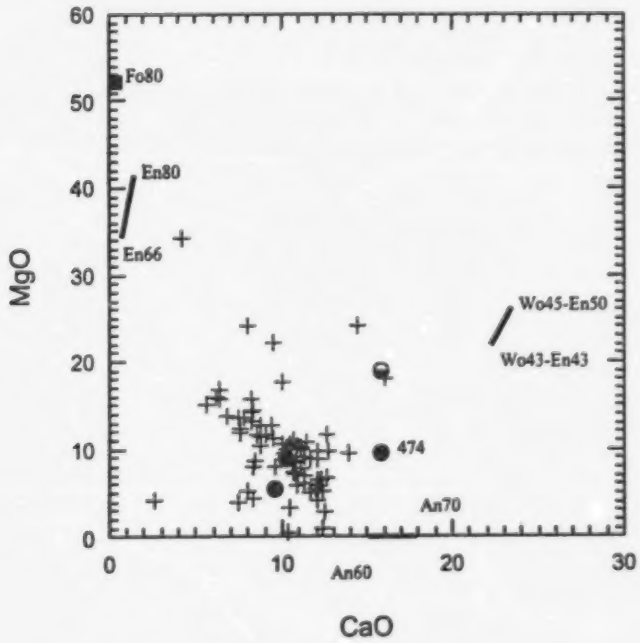


Figure 12b. MgO - CaO for the gabbro and pyroxenite intrusions with samples from Lac des Iles as crosses (Ontario Geological Survey, unpublished data, 1999; after Sutcliffe et al., 1989).

(Figure 8b), and the REE abundances and ratios are comparable to the low Ti basalts (Figure 13a). The positive anomaly in Figure 13a is a result of the high TiO_2 abundance in massive sample 439. The negative anomaly for Nb matches the values observed in the basalts, and the high Ta values are probably a result of analytical error.

Elemental abundances and are interpreted to indicate a relatively evolved source composition for these rocks in a primitive or back-arc setting. An overlap with the basalt compositions indicates that the gabbro is not the cumulate or residual phase of the basalts. The major element abundances of these units are comparable gabbroic rocks of the Lac des Iles Complex (LDIC: Sutcliffe et al., 1989; Figure 12a). This diagram indicates a mixing of orthopyroxene and plagioclase similar to the igneous trend suggested for the LDIC by Sutcliffe et al. (1989). However, the trace element and REE abundances are higher, and the La/Yb normalized ratios are lower, than all but the most evolved units of the LDIC (Figure 13b). The gabbroic to pyroxenitic rocks of the sanukitoid suite of the Roaring River Complex (RRC) are located about 25 km northwest of the late gabbro intrusions. A single analysis reported by Stern and Hanson (1991) has major element abundances similar to the late gabbro intrusions. The trace and RE element abundances are quite distinctive with 958 ppm Sr , 212 ppm Ba and a La/Yb normalized ratio of 18.7. This La/Yb ratio is much higher even than the LDIC ratios of 1.4 to 4.2. A preliminary interpretation is that the late gabbro intrusions are probably not part of an igneous system comparable to the LDIC, but this interpretation is based on only 3 samples.

Pyroxenite

The pyroxenite located west of Garden Lake has high MgO and lower Al_2O_3 abundances than the late gabbro intrusions (Table 2; Fig 12a and b). These abundances probably reflect a predominantly clinopyroxene – plagioclase mineralogy. Trace element abundances are similar to the late gabbro intrusions and basalts of the Garden Lake belt. The REE abundances are distinctive, with a higher LREE abundances and higher La/Yb normalized ratio than the late gabbro intrusions and basalts (Figure 13a). This sample also has negative Nb anomaly and a probable error in the Ta analysis.

The pyroxenite is interpreted to have an evolved calc-alkaline magmatic source, with a more evolved arc environment than the late gabbro intrusions or the basalts. This unit is not directly related to the basalts of the belt, as evident from the difference in La/Yb ratios. The major element abundances of the pyroxenite are different than most of the units in the LDIC, and are most closely comparable to the ultramafic suite (Figure 12a and b). This rock is composed of predominantly pyroxene in thin section, and the major element concentrations are a reflection of this mineralogy. The REE abundances are higher than the LDIC units, with a steeper La/Yb ratio, intermediate between the LDIC and RRC values (Figure 13b). This sample is interpreted have a similar origin as the rocks in the LDIC, and may be part of a similar intrusion.

RADIOMETRIC AGES

The Wabigoon Subprovince was divided into three regions, an eastern, central, and western, based on differences in lithologies and structural style by Blackburn et al. (1991). The dominantly diapiric units of the central Wabigoon separate the 2775 to 2718 Ma units of the western Wabigoon (Blackburn et al., 1991), from 3050 to 2700 Ma units of the eastern Wabigoon (Stott and Percvial, 2000). The plutonic and thin greenstone units of the central Wabigoon have been subdivided into three parts (e.g. Tomlinson et al., 1998). The greenstone belts of the northern and southern margins of the central Wabigoon contain units of a Mesoarchean age (>2900 Ma).

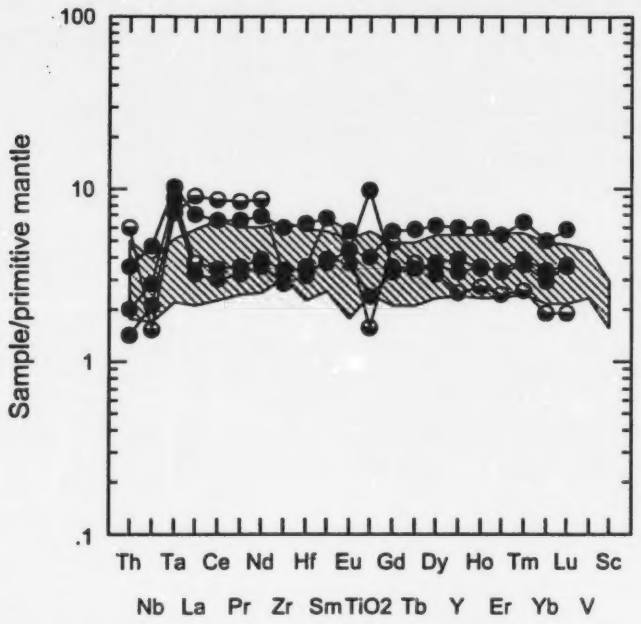


Figure 13a. Mantle normalized extended element diagram of the gabbro and pyroxenite intrusions, with the range range for the Garden Lake low Ti basalt samples (after Wyman and Kerrich, 1997).

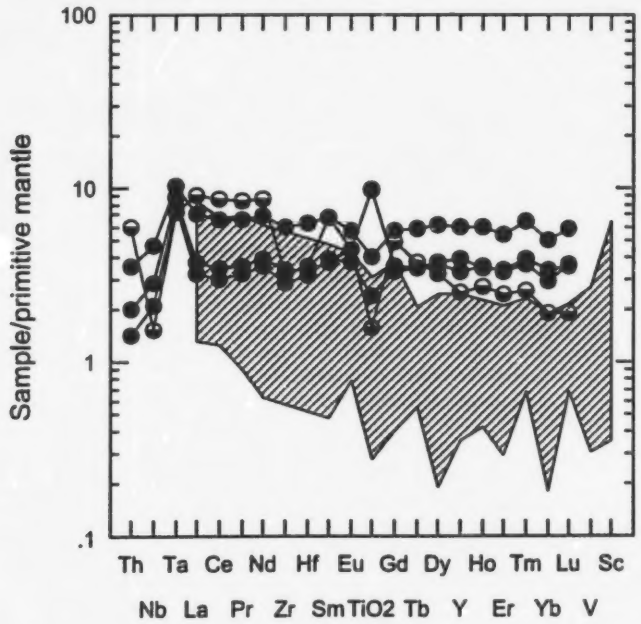


Figure 13b. Mantle normalized extended element diagram of the gabbro and pyroxenite intrusions, with the range for the Lac des Iles samples (Ontario Geological Survey, unpublished data, 1999; after Wyman and Kerrich, 1997).

The middle greenstone belts contain a mixture of Mesoarchean and Neoarchean age units (<2900 Ma; Tomlinson et al. 1998). The extent and significance of Neoarchean units in these middle belts, and the position of the Garden Lake belt within this framework, is not well understood.

A felsic feldspar porphyry dyke from the Point showing was dated at 2710 Ma with 2725 Ma inheritance (D. Davis, unpublished data). This date was reported by Tomlinson et al. (1998) in the work for the OGS-GSC Natmap – Lithoprobe project. This project highlighted the occurrence of allochthonous and autochthonous terranes in the central portion of the Wabigoon Subprovince. Proposed interpretations for this mixture of terranes include a complex history of magmatic intrusion, rifting and/or continental collision for the formation of the central Wabigoon (Tomlinson et al, 1998; 1999). This study highlighted the existence of northern and southern domains in the central Wabigoon with ages of 3100 to 2900 Ma sandwiching the a number of belts with younger ages, including the Garden Lake belt.

The Sibley Group sediments overlie the Archean metavolcanics rocks, and have a radiometric age of 1339+/-33 Ma (Sutcliffe, 1991). Discontinuous diabase sills of the Logan Sill Complex overly all other units in the eastern half of the Garden Lake belt. These sills have a zircon radiometric age of 1108+4/-2 Ma (Sutcliffe, 1991).

Structural Geology

The metavolcanic and metasedimentary rocks of the Garden Lake belt have been tilted, either about a very large regional scale fold axis or by thrust faulting, resulting in a homoclinal east striking south facing sequence. Foliations are moderate to well developed subparallel to the primary structures. Faulting associated with this folding event was conformable to stratigraphy and led to the development of large, belt scale fault zones such as the Garden Lake Deformation Zone (GLDZ). The GLDZ has been active a number of times preceding and following emplacement of the granitoid rocks. Early northwest trend faults were exploited during intrusion and deformation of the granitoid rocks, and results in an irregular northern margin to the belt. A series of northeast trending regional faults have offset stratigraphy within the belt, may have controlled emplacement of the mafic intrusions and are evident in the adjacent felsic intrusive rocks. A late northwest fault displaced the iron formations in the eastern end of the belt, and localized intrusion of the diabase sills.

PRIMARY FEATURES

Some primary depositional features are preserved in widely scattered locations through the belt. Bedding and flow contacts in both the metavolcanic and metasedimentary rocks generally strike east, 080 – 105°, with steep south to vertical dips. Units in the southeast end of the belt, south of the Mooseland River, strike at about 065° with steep south dips. There were few reliable top indicators as pillows are commonly attenuated (length to width ratios of greater than 4:1), and well exposed graded bedding was observed in only a few metavolcanic fragmental and metasedimentary units. A consistent south facing direction is evident based on graded bedding in the tuffaceous conglomerates north of Garden Lake, pillow tops in scattered location on the north side of the belt, cross bedding in a tuffaceous conglomerate sequence north of Kearns, and graded bedding in the southeast end of the belt.

The late gabbro intrusions have igneous layered along the eastern margins. The layers strike at about 050° with apparent northwest dips, subparallel to the trend of the contact with the

adjacent metavolcanic units. The lack of deformation is interpreted to indicate that these intrusions were emplaced during a late event, and are in their original orientation.

FOLIATIONS

Foliations are moderate to well developed being defined by phyllosilicates such as chlorite, sericite and biotite and flattening of pillows and clasts in volcaniclastic and metasedimentary units. The foliations are parallel to subparallel to the primary structures such as flow contacts and bedding. Foliations are generally east trending with steep south to vertical dips with variations in the trend commonly following the contact between the metavolcanic and granitoid rocks. The most noticeable of these deflections is in the three limbs of greenstone extending in a northwest direction into the granitoid rocks. The foliations were probably developed during the event that tilted the rocks of the belt into their current position, with local re-orientation during emplacement of the granitoid rocks.

The massive felsic intrusive rocks are generally weakly foliated in thin section. The lack of platy minerals hinders identification of these structures in outcrop. The foliated granitoid rocks were distinguished from the massive units based on well developed foliations. These rocks have moderately to well developed foliations parallel to compositional layering, and gneissic textures. The trends of the foliations are generally parallel to subparallel to the contacts between the metavolcanic and granitoid rocks.

GNEISSOSITY

The granitoid rocks bounding most of the belt have a moderate to well developed gneissosity. Alternating bands of varying felsic compositions, and rarely amphibolites, are common. Development of a fabric in the bands can be highly variable with adjacent bands ranging from weakly to moderately foliated to gneissic with augen textures. In some areas, especially to the northeast of the belt, pink feldspar augen gneisses are common. The trends of the gneissosity are commonly oriented parallel to subparallel to the contacts between the granitoid and metavolcanic rocks.

Gneissic textures are not well developed in the metavolcanic rocks of the belt, except in a few limited areas. The best example of gneissic textures is along the Hamon Lake road, northwest of Kearns Lake. Compositional banding of a mafic and intermediate material was observed, whether this was an original compositional variation or a metamorphic texture is not known.

LINEATIONS

Few well developed examples of mineral lineations were observed in the predominantly dark green chloritized basalts of the belt. The best lineations were the elongation of clasts in the tuffaceous conglomerates and clastic metasediments. Clasts in the conglomerate on Kearns Lake plunge 60° west along foliation. This orientation is relatively consistent for the western and central portions of the belt. The pink pebble conglomerate toward the southeast end of the belt has elongate clasts plunging 65° east. Due to the different attitude of bedding structure, this lineation direction can only be taken as representative of the units in the immediate area of the sediments. A northeast fault appears to separate this sequence of metavolcanic and metasedimentary rocks from the rest of the belt.

FAULTS

The homoclinal attitude of the metavolcanic and metasedimentary rocks is interpreted to be a result of thrust emplacement of the volcanic rocks (a wedge of back arc oceanic crust) on to a pre-exisitng volcanic sequence (possibly an island arc with a continental basement). The foliations and the belt long GLDZ are interpreted to have begun forming during this event. Strain associated with this initial event was accommodated unevenly, with the iron formations being folded and fracturing brittlely, resulting in highly attenuated or thickened sections. The island arc – back arc environments are interpreted from the lithogeochemical results and the Nd isotopic data (*see* "Lithogeochemistry"; Tomlinson and Percival, *in press*). There is no conclusive evidence to support this model, and the alternative mechanism of folding about an unobserved large regional scale axis is also possible. There are interpreted to be a number of faulting events based on apparent strike deflections and bedding offsets, and regional magnetic survey and Landsat imagery. These faults are discussed in order of their relative ages.

The GLDZ is a ductile shear zone consisting of a series of anastomosing east to northeast trending shears varying in width from about 100 metres to up to 2 km as it passes through Garden Lake. The trace of the zone extends from along the southwest contact between the metavolcanic and granitoid rocks, through Garden Lake, and east along the Mooseland River. A discrete fault zone is not observed, the most intense activity is usually distinguished by a topographic low and an AEM graphite associated conductor in the eastern end of the belt (*see* "Economic Geology"). The fault zone usually is distinguished by an increase in deformation (e.g. Photo 5) and, where exposed on Garden Lake, as a series of discrete intense shears tens of metres thick with relatively sharp boundaries. An example of the relative sharpness of the shear boundaries is observed in the #1 trench of the Bluff Showing, on the southeast side of Garden Lake. A pillowed flow is sheared into a series of chloritic bands over a distance of about 3 m (Photo 13a, b, c). Similar sharp transitions were observed in other locations on the lake. Deformation is generally ductile in nature, except in the area of the Agar Creek showing on the west shore of Garden Lake. In this area, a slight flexure in the trend of the fault is interpreted to result in a small zone of brittle failure (Photo 11; *see* "Occurrences – Agar Creek"). Interpretation of the trace of the GLDZ was aided by the use of IP and AEM survey data completed by Garden Lake Resources (Junnila, 1988, 1989; Figure 2a and b). The GLDZ was reactivated a number of times as evident from an unaltered feldspar porphyritic dyke cutting intensely sheared and iron carbonate altered pillowed flows, approximately 6 m east of the area in Photos 13a (Photo 13d). A sense of displacement in either a horizontal or vertical direction is not clear, but tight folding observed in some units is interpreted to indicate a sinistral offset (e.g. Photo 5). Iron carbonate and quartz deposition during an event pre-dating intrusion of the felsic dykes into this zone is the main host of gold mineralization in the belt (*see* "Economic Geology").

A west trending fault was interpreted to be present north of Garden Lake. The presence of this fault is based on an apparent discontinuity in the AEM and IP anomalies in this area (Figure 2a and b). This fault also offset the iron formations north of Garden Lake in a dextral sense to align with the units north of Kearns Lake. The massive felsic intrusive rocks exploited this zone of weakness along the northern margin. A fault with a similar orientation may also exist along the northeast limb of the belt.

A series of northeast trending faults offset units, creating short strike length AEM conductors in the western end of the belt. These faults are late regional scale structures evident from Landsat imagery in the surrounding granitoid rocks. Brittle structures with similar northeast orientations were observed in some locations along the northwest side of the belt and in the massive felsic intrusive rocks. The sense of motion is interpreted to be both sinistral and dextral

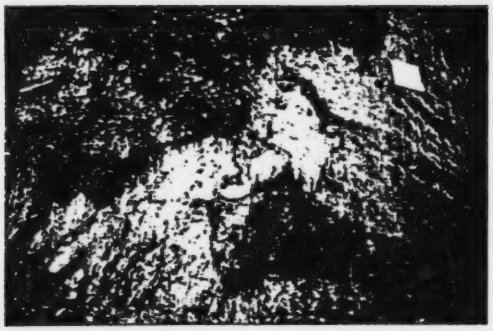


Photo 13a. Point Showing: eastern trench: increased shearing of a pillowed mafic flow from least sheared to the left/north to very intensely sheared to the right/south within one of the discrete shears forming the Garden Lake Deformation Zone. Southeast shore of Garden Lake.

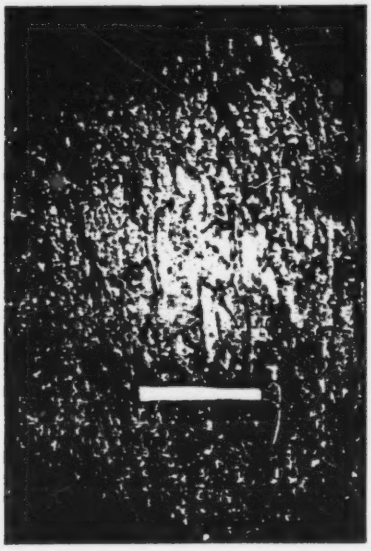


Photo 13b. Point Showing: small, moderately flattened pillows in the least sheared area of the trench; note the hammer on the left side of Photograph 13a.

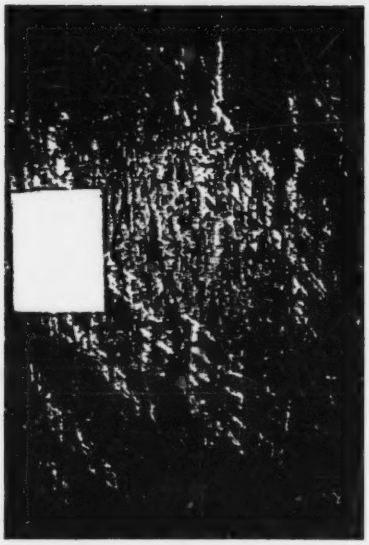


Photo 13c. Point Showing: very intensely sheared pillows with strong iron carbonate alteration; note the clipboard on the right side of Photograph 13a and the similarities with Photograph 12 from the Bluff showing.

Photo 13d. Point Showing: undulating contact of a later feldspar porphyritic dyke cross cutting the intensely sheared pillowed flow; located to the top of Photograph 13a.

based mainly on the proposed position of the central metasedimentary band, with the magnitude of the displacements being interpretative. These late brittle faults are also interpreted to have offset the belt margins.

A number of north trending brittle faults are also interpreted based on Landsat and observed topography. Two of the most obvious of these faults are the stream valley leading into the south end of Kearns Lake, and the east shore of Conick Lake. Both of these features are steep topographic breaks associated with known gold mineralization (*see* "Occurrence – Kearns Road"). It is not known whether these structures are related to the mineralization, or simply cut existing mineralization. These faults are late features, and are also evident as topographic features in the surrounding granitoid rocks.

A late, regional scale fault passes through the southeast portion of the belt. This fault separates the northeast striking metavolcanic and metasedimentary units from the rest of the belt. The late gabbro intrusions straddle this feature, and the shears along the northwest contact of the gabbro are subparallel to the trend of the fault. Displacement or sense of motion of this fault is not known, but movement on this fault probably caused the different orientation of the units to the south.

A northwest trending fault is interpreted from the displacement of the iron formations east of Garden Lake. Displacement has a dextral sense with the iron formations indicating an approximately 2 km offset. The GLDZ changes direction across this fault, suggesting that there may have been some rotational movement. Late fractures offsetting the igneous layering in the gabbro intrusions have a similar 130° orientation suggest possible subsidiary structures. This fault appears to have influenced the emplacement of the diabase sills, resulting in elongate northwest trending ridges.

Economic Geology

Mineralization in the Garden Lake belt is localized along late structures, or associated with iron formation or the late mafic intrusions. Mineralization in the remainder of the map area is minor and generally restricted to disseminated pyrite and minor pyrrhotite associated with quartz veining. Past prospecting of the central and western portions of the belt has failed to discovery any significant mineralization apart from the historic showings. Samples collected during this mapping program generally confirm this observation. Areas in the belt not fully assessed by this program include the eastern portion of the belt, along the Kitchen Lake and Holinshead Lake roads, covering the eastern extension of the GLDZ, and the late mafic intrusions. Sampling during this mapping program indicated a new occurrence of gold associated with quartz and iron carbonate veining south of Kearns Lake (*see* "Kearns Road").

GOLD

Intense iron carbonate alteration, moderate sulphide mineralization, quartz veining and intense shearing are common to most gold occurrences in the Garden Lake belt. Other than the Conick Lake occurrence, the gold showings are hosted by the intensely deformed and altered rocks within the GLDZ. High arsenic values reported from the Bluff showing indicate a connection between the mineralization in the GLDZ and the Conick Lake showing. Similar alteration and deformation in the west and east ends of the belt along the possible eastern extension of the GLDZ are potential exploration targets. Quartz veining and mineralization outside of the

intensely altered and deformed zones was not significant. The timing of the mineralizing event appears to pre-date the intrusion of the felsic dykes as the dykes and the veining associated with the dyke appears to be unmineralized.

The quartz veins present throughout the belt are generally folded and boudinaged, ranging from less than a centimetre to a few tens of centimetres in width, but rarely traceable more than 5 m. The veins usually lack sulphide or carbonate mineralization, or wallrock alteration. None of the samples of this type of material returned significant gold values (Table 3).

Intensely sheared and iron carbonate altered mafic metavolcanic rocks occur along the Kitchen Lake road. The units in this area vary from a finely crenulated, iron carbonate altered rock with fine, <0.5 cm, ribbons of white quartz, to lenses of lean iron formation with 1 to 2% very fine grained pyrite. The crenulated rocks are intensely chloritized and carbonatized units with up to 10% sulphides. An outcrop in this area had been described as a severely crenulated feldspar and biotite rich rock of unknown origin with mylonitic features by Lavigne et al. (1990). Samples of the lean iron formation and iron carbonate altered sulphide rich unit returned no detectable gold upon assay (Table 3). These units resemble the units observed in the trenches of the gold showings on Garden Lake, within the GLDZ. This area is also located to the east of the lake sediment anomalies (Jackson and Dryer, 2000) along the same east trending structure representing a possible eastern extension of the GLDZ.

Quartz veins typically occur in one of the joint sets of the massive intermediate to felsic intrusive rocks. The veins are commonly 3 to 5 cm wide, but may be up to 10 cm wide, and can not usually be traced more than 5 m. The quartz is white to rarely gray, with variable but commonly high amounts of albite and up to 2% fine grained pyrite. Alteration of the felsic intrusive rock next to the veins is rare, and confined to <1 cm wide chlorite or weak potassium feldspar alteration. No significant assay results were obtained from any of the veins and wallrock samples (Table 3).

SULPHIDES / BASE METALS

Sulphide minerals are common accessory phases in all of the supracrustal rocks of the Garden Lake belt, and associated with quartz veining in all of the gold showings. Significant amounts of primarily sulphide minerals are most commonly associated with the iron formations or interflow units and to a lesser extent with late structures. The largest accumulations of sulphide mineralization are associated with iron formation and interflow material in the Bumbu showing, and iron formation and late structures in the Mooseland area. Some workers have suggested that there is a lateral transition from oxide to sulphide facies in the iron formations north of Garden Lake (e.g. Pitman, 1991). This transition was not observed, and the occurrence of oxide facies iron formation and sulphide in the same trench at the Bumbu showing is interpreted to indicate a slightly later synvolcanic hydrothermal event. There are a number of small occurrences of sulphide minerals scattered through the belt.

Sulphides are present in a shear within a 10 to 15 m wide iron formation, located northwest of the Bumbu showing. The shear is approximately 0.4 m wide trending subparallel to the bedding in the iron formation. There is 3 to 5% fine grained pyrite with minor pyrrhotite, and precious and base metal values are close to or below detection (sample 34; Table 4).

Sulphide was observed in two subparallel bands hosted by mafic metavolcanic rocks along the north east margin of the belt. The bands are 3 to 5 cm wide in highly deformed mafic flow and trend in a north west direction subparallel to the bedding and the contact with the foliated

Table 3. Assay results for gold related sampling.

Field Number		46c	46b	46a	4	8	13	34	100	144	207	2071	2090	2072
Lab number		99TRH-001	99TRH-002	99TRH-003	99TRH-004	99TRH-005	99TRH-006	99TRH-007	99TRH-008	99TRH-009	99TRH-010	99TRH-011	99TRH-012	99TRH-013
	detection limit													
UTM East		297289	297289	297289	292685	292761	293360	292994	291484	282543	280629	280426	278210	280171
UTM North		5492851	5492851	5492851	5491084	5490755	5490941	5492406	5493250	5485798	5486135	5484652	5484423	5484880
UTM Zone		16	16	16	16	16	16	16	16	16	16	16	16	16
	ppm													
Au	0.01	n.d.	0.08	n.d.	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ag	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Be	3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Co	5	22	78	21	n.d.	n.d.	62	n.d.	42	9	54	48	n.d.	n.d.
Cu	5	144	450	279	n.d.	n.d.	15	8	1434	66	101	189	10	12
Mo	8	8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	9	n.d.	n.d.	10	11
Ni	5	30	114	32	n.d.	7	45	8	91	19	62	80	n.d.	6
Sc	1	4	32	9	n.d.	n.d.	7	n.d.	31	6	36	36	n.d.	n.d.
Sr	1	6	98	12	11	12	276	1	89	77	140	181	14	7
V	5	33	254	72	n.d.	8	65	7	243	60	380	373	5	10
W	40	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Zn	2	31	109	29	4	18	67	7	155	34	139	161	2	7

field number	description
46c	arsenopyrite in white quartz vein
46b	pyrite in chloritic shear next to vein
46a	pyrite and arsenopyrite in quartz vein
4	minor pyrite and potassic alteration
8	minor pyrite and quartz lenses and pods
13	10-20% medium - fine grained pyrite in ductile shear with grey quartz +/- albite pods
34	sheared iron formation with 20-25% fine grained pyrite
100	3-5% coarse grained pyrite along fractures between mafic xenolith and granite gneiss
144	thin boudined iron formation with trace pyrite
207	irregular pods of white quartz - 0.5-30 CM
2071	30 cm cherty quartz vein parallel to foliation
2090	rusty quartz vein
2072	very sheared mafic volcanic at granite contact

Table 3. continued

Field Number		3014	282	287a	287b	287c	365	372v	372w	380	2242	461	468a	468b	468c
Lab number		99TRH-039	99TRH-040	99TRH-041	99TRH-042	99TRH-043	99TRH-044	99TRH-045	99TRH-046	99TRH-048	99TRH-050	99TRH-052	99TRH-058	99TRH-059	99TRH-060
	detection limit														
UTM East		298079	292967	292502	292502	292502	297235	280528	280528	310461	299582	316915	312115	312115	312115
UTM North		5491497	5487432	5488482	5488482	5488482	5490107	5485084	5485084	5490002	5490851	5492992	5490977	5490977	5490977
UTM Zone		16	16	16	16	16	16	16	16	16	16	16	16	16	16
	ppm														
Au	0.01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.69	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Ag	0.1	0.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Be	3												n.d.	n.d.	n.d.
Co	5												13	10	7
Cu	5												30	23	23
Mo	8												n.d.	n.d.	n.d.
Ni	5												27	21	19
Sc	1												4	4	4
Sr	1												36	41	48
V	5												34	39	40
W	40												n.d.	n.d.	n.d.
Zn	2												42	66	44

field number	description
3014	pyrite and minor chalcopyrite in white quartz vein
282	carbonate alteration and 2% disseminated pyrite
287a	very minor green mica, iron carbonate, and 3-5% fine grained disseminated pyrite in iron carbonate altered wallrock: Agar Creek
287b	white quartz veinlet with iron carbonate halo containing 5% disseminated fine grained pyrite - Agar Creek shwoing
287c	iron carbonate alteration with minor green mica and fine grain disseminated pyrite: Agar Creek
365	tourmaline in quartz vein
372v	25% iron carbonate and 3-5% fine to very fine grained pyrite: Kearns Road
372w	2-3% very fine grained disseminate pyrite: Kearns Road
380	quartz rich band in foliated intermediate volcanic, possible eastern extension of the Bluff showing
2242	Bluff showing
461	quartz-chlorite-potassium feldspar-hematite veinlets in mafic volcanic rocks
468a	pyrite clasts in conglomerate
468b	pyrite and pyrrhotite stringers in conglomerate
468c	sulphide clasts and stringers in conglomerate

Table 4. Assay results for base metal related sampling.

Field Number		2074	tr2	18a	18b	2539	378	381	tr3	tr4	2454a	2454b	2552	264	386
Lab number		99TRH-014	99TRH-015	99TRH-034	99TRH-035	99TRH-038	99TRH-047	99TRH-049	99TRH-054	99TRH-055	99TRH-056	99TRH-057	99TRH-061	99TRH-085	99TRH-086
	detection limit														
UTM East		279807	293916	294022	294022	312269	310049	310595	293838	293825	314435	314435	312671	281811	312617
UTM North		5484559	5492598	5492607	5492607	5491717	5489907	5490346	5492569	5492479	5497359	5497359	5492691	5489360	5494897
UTM Zone		16	16	16	16	16	16	16	16	16	16	16	16	16	16
	ppm														
Au	0.01	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.				n.d.	n.d.	n.d.	n.d.	n.d.
Ag	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	0.1				n.d.	n.d.	n.d.	3	2
Be	3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		
Co	5	44	104	123	71	36	25	18	111	18	59	47	48		
Cu	5	403	247	83	114	51	175	81	181	958	356	395	176	144	11
Mo	8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		
Ni	5	59	126	76	77	115	83	38	80	148	138	83	44	105	6
Sc	1	14	3	10	24	41	8	4	8	20	17	22	33		
Sr	1	12	1	18	50	189	68	23	19	49	99	51	179		
V	5	123	39	97	200	230	75	36	91	229	166	211	421		
W	40	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		
Zn	2	1026	71	72	108	111	30	84	85	180	227	348	57		

field number	description
2074	sulphides along fractures, possibly interpillow
tr2	semi-massive sulphide
18a	trench 1; with sulphide along fractures
18b	trench 1; with chert and sulphides
2539	up to 10% disseminated pyrite
378	15 TO 20% pyrite in brecciated chert
381	1-2% very fine grained pyrite in lenses <2 mm
tr3	massive sulphide
tr4	disseminated to semi-massive sulphide
2454a	sulphide in shear, possibly metamorphosed interflow iron formation
2454b	sulphide in shear, possibly metamorphosed interflow iron formation
2552	trace disseminated fine grained pyrrhotite and pyrite
264	2-4% very fine grained pyrite disseminate and in lenses
386	lapilli tuff or sediment

granitoid rocks. The sulphides are a mixture of 30 to 50% pyrite and pyrrhotite in a matrix of recrystallized quartz or chert. The best assay contained 395 ppm Cu and 348 ppm Zn, with no detectable precious metals (samples 2454a and b; Table 4).

A conglomerate located north of the diabase along the Kitchen Lake Road contains 5 to10% sulphide clasts (*see* "Clastic Metasedimentary Rocks"). The sulphides are predominantly pyrite with minor pyrrhotite. The origin of the sulphide clasts is not known, but transport could not have been for any great distance. Three samples of this material were assayed returning low base metal and below detection precious metal contents (samples 468a, b, and c; Table 4).

Minor accumulations of sulphide minerals occur in an interflow cherty material situated between mafic metavolcanic units, south of Kearns Lake. The cherty material is highly sheared, and could have been either a chert bed or quartz vein. The sulphides are mainly pyrite with minor pyrrhotite and contained anomalous Cu and Zn values (403 and 1026 ppm respectively in sample 2074; Table 4).

An occurrence of small lenses of pyrite hosted by mafic metavolcanic rocks on the south shore of Stonehouse Lake was reported by Milne (1964). No assays were completed and subsequent prospecting has not lead to the report of any economically significant values from this area.

PLATINUM GROUP ELEMENTS

The late gabbroic intrusions located in the eastern portion of the Garden Lake belt, along the Mooseland River, contain highly variable amounts of sulphides either as disseminated grains or within shears. East of the Mooseland River, the gabbro contains disseminated, fine to medium grained pyrrhotite and pyrite constituting less than 1% of the rock. West of the river, fine to grained sheared gabbro zones up to 1 m wide, and oriented approximately north-south or east west may contain 3 to 5% fine grained pyrite with minor pyrrhotite. The shears may contain ribbons of quartz and epidote mixed with highly chloritized very fine grained gabbroic material, and 10 to 20 cm lenses of less sheared and altered gabbro. These shears may be the result of interaction between the intrusion and the adjacent metavolcanic country rock. Barren white quartz veins up to 10 cm wide are present along the south side of the intrusions. The veins may occur in fractures or associated with the coarse grained hornblende quartz gabbro. There is little to no sulphide associated with these veins, although up to 1% medium grained, anhedral pyrite may be located along the contacts or in the adjacent gabbro. Samples of the shear, massive gabbro, and layered gabbro were analysed for PGE, with high values of 36 ppb Pt, 24 ppb Pd only slightly above background (Table 5).

The pyroxenite located west of Garden Lake has medium to coarse grained hornblende gabbro phases along the eastern contact. The pyroxenite has disseminated fine grained blebs of pyrite and lesser pyrrhotite, and disseminated magnetite. Quartz veining is common in the hornblende gabbro portion of the intrusive, usually occurring along fractures with minor shearing trending east to northeast. The quartz is usually white with no associated sulphide mineralization, although two veins further east contain minor chlorite or epidote staining resulting a vein with a light green . Bleaching of the gabbro may occur next to the veins. Minor shearing occurred in a 090° joint in one outcrop, with minor associated iron carbonate alteration. A samples of the pyroxenite contained less than detection limits in Pt and Pd (Table 5).

Table 5. Assay results for platinum group element related sampling.

Field number		2522	2523	435	439	474b	2576	474a	2579	444
Lab number		99TRH-036	99TRH-037	99TRH-051	99TRH-081	99TRH-053	99TRH-062	99TRH-082	99TRH-083	99TRH-084
	detection limit									
UTM East		312129	312208	311465	311808	315295	314539	315295	312463	290769
UTM North		5492360	5492344	5492326	5491936	5492729	5492802	5492729	5492463	5487595
UTM Zone		16	16	16	16	16	16	16	16	16
	ppb									
Au	0.01	n.d.	n.d.	n.d.	13.2	n.d.	n.d.	n.d.	n.d.	5
Pt	8	22	36	n.d.	32	n.d.	n.d.	n.d.	9	n.d.
Pd	8	14	24	n.d.	47	n.d.	n.d.	n.d.	n.d.	n.d.

field number	description
2522	sulphide in gabbro
2523	rusty sulphide in fracture
435	mineralized shear
439	sheared with quartz and epidote, 3-5% fine grained pyrite and pyrrhotite
474b	minor chalcopyrite in layered gabbro
2576	trace disseminated fine grained pyrrhotite and pyrite
474a	massive gabbro south of the layered sequence
2579	massive gabbro
444	massive gabbro

MAGNETITE

Interflow metasediments, consisting of banded oxide facies chert-magnetite iron formation, are the main host for magnetite in the Garden Lake belt (*see* "Chemical Metasedimentary Rocks"). Minor magnetite also occurs in magnetiferous metasediments, generally in areas of higher metamorphic grade. The iron formations are lean, with the magnetite rich beds of the iron formations containing between 15 and 30% magnetite. The thickest accumulations of iron formation are located west of the Bumbu showing, north of Garden Lake, and north of Kearns Lake, may be the result of tectonic thickening. These iron formations outcrop as attenuated beds in the Conick Lake area, and were intersected in drill hole in the Mooseland River area. Highly attenuated iron formation units are also observed in the areas south of Kearns Lake.

HEMATITE

Specular hematite is common in fractures with quartz or quartz-feldspar in the mafic metavolcanic rocks along the Kitchen Lake road. The occurrence of hematite increases to the east and is associated with druzy quartz on the eastern margin of the belt. The hematite may be related to a late granitic intrusion further to the east.

Occurrences

Exploration in the Garden Lake belt has been sporadic since the initial prospecting for gold in the 1920s led to the discovery of gold on the east shore of Conick Lake (Milne, 1964). This initial work was followed up in 1946, and exploration was expanded to the rest of the belt resulting in the outlining of the Bluff and Point showings on the southeast shore of Garden Lake (Phelan, 1946). Other than a brief period of base metal exploration in the 1960s, there was a hiatus in recorded exploration until about 1983. Since that time, a number of companies have conducted exploration programs in the Garden Lake belt. These efforts are described below by commodity type, gold and base metals.

GOLD

The Garden Lake belt was initially explored for gold in the 1930s which led to the discovery of gold on the east shore of Conick Lake (Milne, 1964). The showing was reported to host visible gold, but no assays were reported. The first documented gold exploration was trenching and sampling of the Conick Lake showing by Little Long Lac Gold Mines Ltd. in 1946 (Phelan, 1946). Little Long Lac Gold Mines also completed trenching and sampling of the Bluff showing and sampling of the Point showing, on the southeast shore of Garden Lake.

There was a hiatus in recorded gold exploration until the ground around the eastern end of Garden Lake was staked by C. Bumbu in about 1983. Garden Lake Resources Ltd. optioned the property in 1986, and had an airborne helicopter geophysical survey flown by Aerodat Ltd. over an area extending from east of Garden to west of Kearns Lake. An IP survey, with a dipole-dipole configuration, was completed over Garden Lake (Junnila, 1988), followed by a second IP survey over the Conick Lake and Bumbu showings (Junnila, 1989).

Claims covering Garden Lake, and including the Bluff, Point and Agar Creek Showings, were staked by the Stares brothers in 1996 and optioned to Battle Mountain Canada Inc. in 1997. Battle Mountain completed a program of prospecting, geophysical compilation, geological

mapping, soil sampling and lithogeochemistry (Londry, 1997). The property was subsequently optioned by Band Ore Resources Ltd. in 1999, but the option was abruptly terminated. Greater Lenora Resources Corp. and RJK Exploration Ltd. currently hold the property under option and completed a diamond drill program in the fall of 1999.

Conick Lake

Gold was discovered in the 1930s on the east shore of Conick Lake, but no assays are reported (Milne, 1964). Little Long Lac Gold Mines Ltd. completed a program of trenching and sampling in 1946, on a quartz stringer on the east shore of Joe Lake (Conick Lake; Phelan, 1946). The stringer is described as being 91.4 m long and 7.6 to 30.5 cm wide, diagonally cutting an iron formation. Some visible gold was observed associated with pyrite, chalcopyrite, arsenopyrite, and tourmaline. The best assays were 1.5 oz Au/t over 10.2 cm in a quartz sample with abundant cubic pyrite and 0.79 oz Au/t over 5.1 cm in quartz with arsenopyrite. The stringer was stripped for the full length and exposed by a 12.2 m wide trench. The stringer was shown to be an isolated lens with no continuity.

The area of the showing was staked about 1983 by C. Bumbu, and the trench was partially cleared. An airborne electromagnetic (EM) and magnetic survey was conducted over the showing by Garden Lake Resources Ltd. in 1988 (Junnila, 1988) followed by an induced polarization (IP) survey in 1989 (Junnila, 1989). The area around the showing was gridded and mapped, outlining a sequence of chlorite schist/mafic tuff, pillowed flows, carbonate rich sediments, graphitic shale, iron formation. Stratigraphic tops are to the south, with a foliation to the northeast dipping steeply southeast. These units correlate well with the anomalies observed in the EM and IP surveys completed over the area. The trench was mapped and 11 samples collected and assayed. The trench contained a network of 0.5 to 5 cm sugary quartz veins containing 3% pyrite, a 1 m wide iron formation, and a chlorite schist with 1 to 25% pyrite (averaging 5% pyrite) and up to 2% arsenopyrite. The best assays were:

Assay (g Au / t)	Rock Type	Mineralization
6.58	sugary quartz	2% pyrite
8.92	sugary quartz in chlorite schist	
31.48	sugary quartz	1% pyrite, 2% arsenopyrite

However, most of the samples from the area returned 0.03 g Au/t.

A property visit by the staff of the Resident Geologist's office reported a quartz vein system exposed in a small gully on the east shore of Conick Lake (Lavigne et al., 1990). The quartz veins is reported to be up to 45 cm, but more commonly 30 cm wide containing pyrite, arsenopyrite, and tourmaline. The quartz vein system is described as subparallel to an axial planar cleavage associated with a fold structure exposed in cross section along the southeast shore of Conick Lake. An arsenopyrite rich sample collected from this trench contains visible gold (J. Scott, personal communication, 1999).

The quartz vein currently exposed in the trench of the Conick Lake showing is white with 5 to 10% pyrite, chalcopyrite and arsenopyrite concentrated in the margins of the vein. There is a similar 5 to 10% sulphide in the highly chloritized wallrock. The iron formation exposed near the top of the hill is a 20 to 30 cm wide unit. Three samples were collected from the trench with the following results:

Sample Number	Assay (ounces Au / t)	Rock Type	Mineralization
46a	0.10	white quartz	pyrite, arsenopyrite
46b	0.08	chloritic shear vein margin	pyrite, arsenopyrite
46c	n.d.	white quartz	arsenopyrite

These samples also contained anomalous Cu (Table 3). This showing differs from the others in the belt due to the high arsenopyrite content, and the location outside of the GLDZ. The airborne geophysics and Landsat imagery have been interpreted to indicate a north trending fault passing through Conick Lake.

Inco drilled two holes in 1966 to investigate coincident airborne magnetic and EM anomalies approximately 400 m east and 600 m southeast of the Conick Lake showing. The eastern hole (30622) was 79.6 m long, and intersected chert breccia and sericite schist. The breccia and schist was described as being mineralized to strongly mineralized with pyrite over approximately 10.4 m. The southeast hole (30619) was 31.4 m long and intersected very weakly mineralized chlorite schist. No assays accompanied these drill logs.

Bluff

Gold was discovered on the south east shore of Garden Lake by Little Long Lac Gold Mines Ltd. in 1946, and was considered to be the main gold showing during the exploration program (Phelan, 1946). A series of 8 trenches were completed, the area was prospected, and 3 drill holes totaling 392.5 m tested the mineralization. The rocks were described as being highly carbonatized and silicified schists with numerous sulphide veinlets and stringers, disseminated sulphide, and rare quartz stringers with green carbonate. The sulphides consisted of mainly pyrite with minor chalcopyrite, arsenopyrite and galena. The green carbonate was described as mariposite, although no mineralogical work was completed. Gold was found to be associated with small shoots of enriched gossan, with a best assay of 0.52 oz Au/t from a grab sample. Most of the sulphides were barren, with assays of 0.01 to 0.02 oz Au/t. Gold bearing float returned better values, consistently in the range of 0.10 oz Au/t, but could not be traced to a source. Thin, 0.32 to 0.64 cm, seams of sulphide consisting of nickeliferous pyrite, millerite and gersdorffite were also reported in the trenches. These seams generally assayed in the trace to 0.20% Ni range, but values up to 1.46% Ni were also reported. These seams, hosted by highly siliceous schist with mariposite and ankerite, could not be traced for any distance. Drill holes 1 and 3, located to the west of the trenching, were drilled to the south and north respectively. Hole 2, collared in the western most trench, was drilled towards the south. Hole 4 was located approximately 300 m offshore to the northwest and drilled towards the south to a depth of 189.7 m. The best assay from any of the holes was 0.02 oz Au/t. This drilling suggests that the GLDZ is approximately 400 m wide, between holes 1 and 4, in this area (*see* "Structure").

The next recorded work was by C. Bumbu who staked the area and cleared out the old Little Long Lac Mines trenches during the period 1983 to 1985. Garden Lake Resources optioned the property and completed power stripping of 5 trenches, geological mapping, and sampling at 1 metre intervals for a total of 254 assay samples (Junnila, 1989). The quartz-carbonate veins and lenses are roughly parallel to foliation were observed in a new trench along the shore of the lake. The veins ranged from a few millimetres to 1 m in width, with a maximum vein length of about 1 metre. Bright green mica, termed fuchsite in the reports, was ubiquitous in silicified zones. Assay results averaged 0.001 oz Au/t.

The Bluff showing was covered by a claim block staked by the Stares Brothers in 1996, and initial sampling of the trenches returned a high assay of 0.013 oz Au/t (Stares, 1997). Sampling of other areas of alteration and quartz-carbonate veining on the islands and along the eastern shore of Garden Lake yielded a best assay of 456 ppb Au in a silicified sheared mafic volcanic float with 15 to 20% pyrite. A total of 13 samples were analysed for whole rock major elements by XRF, but no significant K_2O or Ba enrichment was observed. Two lake sediment samples were

collected and returned 6 and 8 ppb Au. Additional sampling of the rocks in the trenches of the Bluff Showing returned a high value of 0.12 oz Au/t from an altered white porphyry with 5% pyrite (Stares, 1997b). The property was optioned to Battle Mountain Canada Inc. in 1997, and a program of prospecting, geophysical compilation, geological mapping, soil sampling and lithogeochemistry (Londry, 1997). A total of 92 assay samples, including 50 for whole rock analyses, and 373 humus and B horizon soil samples were submitted. The best assay was 1663 ppb Au, while separate samples returned high values of 3132 ppm As and 1649 ppm Ni. The geophysical compilation highlighted the broad, minimum 100 m wide, IP response over the deformation zone extending the length of the lake. Mapping characterised the rocks within the deformation zone as being sheared mafic volcanics strongly carbonatized with localized albitic alteration and green mica. The interpretation was that the deformation zone was the western extension of the Paint Lake Fault, host to the Brookbank Deposit in the Geraldton area (Londry, 1997).

The property is currently under option to Greater Lenora Resources Corp. and RJK Exploration Ltd. These companies completed a program of 2 diamond drill holes, totaling 387 m, in the fall of 1999 (Belanger, 1999). The holes tested IP anomalies from the Garden Lake Resources survey, located along the south shore of Garden Lake, in the area of the Bluff showing. The holes are reported to have intersected extensive multiple sequences of carbonates, ferruginous dolomite and mudstone, with multiple pyritic zones in the mudstone. Only anomalous gold values over wide widths are reported. The extent, intensity and style of alteration was compared to alteration observed in the Larder Lake Break in the Virginatown area.

The rocks currently exposed in the trenches resemble the intensely sheared and iron carbonate altered mafic metavolcanic rocks observed in the eastern trench of the Point showing (*see* "Point"). The rocks are dark green to medium brown, intensely sheared and altered containing disseminated sulphides or lenses of up to 5% sulphide. The sulphide is mainly pyrite with lesser pyrrhotite (Photo 12). A number of white quartz veins containing variable amounts of iron carbonate, 1 to 2% sulphide and generally a significant amount of green mica are most prominent in the north end of the two trenches closest to the lake shore. A single sample of the quartz veining with green mica returned no detectable gold (sample 2242; Table 3). The discrepancy between the grab samples and the detailed sampling by a number of workers (e.g. Junnila, 1989; Stares, 1997a, b) indicates that the controls on gold mineralization in this area are not well understood. A detailed sampling program with short sample lengths, the use of a larger assay weight, and/or metallic separates would aid in the identification of the features control the gold mineralization.

Point

Little Long Lac Mines Gold Ltd. conducted the initial exploration of the gold showing located on the point situated along the south east shore of Garden Lake, west of the Bluff showing (Phelan, 1946). The gold bearing units at the Point showing are described as being quartz filled shear zones in an arkose with coarse cubic pyrite and galena. The best grab sample returned 0.22 oz Au/t, but could not be duplicated by additional sampling or a single diamond drill hole with a length of 194 m.

A sample by C. Bumbu in 1984 assayed of 8.5 g Au/t across 3 m in pyritized and cherty buff coloured carbonate rocks (Junnila, 1989). A grab sample during a property visit by Garden Lake Resources returned 23.3 g Au/t. The IP survey identified a string of anomalies located under the lake, north of the Point showing. These results lead to a program of power stripping in 11 areas, geological mapping and collection of 52 samples for assay. The rocks in the trenches were

described as a 600 m thick succession of, from north to south, chlorite schist / mafic tuff, sedimentary carbonate-chlorite schist, chlorite schist, and pillowed flows. This succession youngs to the south, with foliations trending south west. Numerous small quartz-carbonate veins parallel to foliation generally contain 1% pyrite. Assays from the sampling program averaged 0.03 g Au/t, and re-sampling of the original trench could not confirm the previously reported gold value.

The showing was visited by the Resident Geologist's staff in 1989, before the stripping was conducted by Garden Lake Resources (Lavigne et al., 1990). The rocks were described as a sheared, buff tan coloured, sericitized feldspar porphyry with relict feldspar crystals and pyrite cubes up to 0.5 cm. A sample of this material assayed 630 ppb Au.

Many of the structural, metamorphic, and alteration features have been discussed in previous sections of the report (*see* "Structure", "Metamorphism", "Alteration", "Granitoid Rocks – Dykes"). The following is a brief summary of these features. The main rock types in the trenches are basaltic flows and pillowed flows intruded by porphyritic felsic dykes. In some cases the dykes intrude at a shallow angle to the bedding. The basalts are variably sheared, ranging from undeformed pillowed flows on the south to intensely sheared banded chloritic units on the north, in the GLDZ. The intensely sheared units are very strongly iron carbonate altered. The dykes are also highly deformed within the GLDZ, moderately carbonatized, with quartz veining containing minor tourmaline and 1 to 2% pyrite. Quartz veining with tourmaline was not observed elsewhere in the belt. A sample of the quartz veining with tourmaline contained no detectable gold (sample 365; Table 3).

Agar Creek

The Agar Creek occurrence is located on the west shore of Garden Lake, close to the mouth of Agar Creek. The showing was initially reported by Little Long Lac Gold Mines, and noted on maps of the Garden Lake by subsequent companies. Little work appears to have been completed, except for minor stripping and blasting of two trenchings on the shore of the lake by C. Bumbu.

Little Long Lac Mines initially described the occurrence as a silicified and sheared arkose containing small quartz veinlets, pyrite, galena and minor gold (Phelan, 1946). A property visit by the staff of the Resident Geologist's Office described the occurrence as being a zone displaying progressive shearing from a fresh quartz feldspar porphyry to a sericite schist (Lavigne et al., 1990). Quartz and quartz-carbonate veins form small scale ladder vein structures within the zone, accompanied by carbonate alteration and disseminated 2 to 3 mm euhedral pyrite. The quartz veins are white to dull gray and are commonly less than 15 cm wide, but permeate the trench area. The white quartz was interpreted to represent silicification rather than fracture filling gray quartz. Chloritic wisps delineate the anastomosing cleavage within and subparallel to the shear zone. Lavigne et al. (1990) recorded values of 0.01 to 0.26 oz Au/t reported by C. Bumbu, with a government sample returning 33 ppb Au, 690 ppm Cu and 360 ppm Zn.

Exposures in the trenches of the Agar Creek occurrence are highly weathered, obscuring many of the finer textures. The impression is that the white quartz veinlets occupy brittle fractures resulting in a ladder vein pattern within a gray to light brown alteration (Photo 11). The veins have a halo of light brown iron carbonate alteration and disseminated, 1 to 2%, euhedral pyrite. Traces of a green carbonate or mica was observed in one sample. Three samples were collected, one highly veined and two iron carbonate altered wallrock. The assays were all below detection for Au and Ag (samples 287a, b, and c; Table 3). Veining at this occurrence is in a brittle structure in marked contrast to the intensely sheared metavolcanic rocks of the Point and Bluff Showing. As suggested above (*see* "Structure"), this occurrence is interpreted to be located at a

slight flexure in the GLDZ. The appearance of this veining with an iron carbonate alteration and disseminated pyrite halo very closely resembles the style of veining and alteration observed at the Anoki Mine, Larder Lake. The gold in the mine was erratically distributed within and about the veins and could only be outlined by detailed sampling.

Ruffo Lake

An airborne anomaly in the area south of a small lake located between Ruffo Lake and McMullen Lake, east of highway 811, was covered by a ground vertical loop survey by Inco in 1966. Initial single hole 30688, of 60 m in length, tested the anomaly located by the ground survey. Additional holes 34409 and 34410, totaling 53.6 m, tested the strike extent and undercut the initial hole. Holes 30688 and 34410 intersected the same northeast trending structure composed of graphitic schist hosted by andesite with narrow quartzite (chert) horizons. The graphitic schist contains up to 20% pyrite and pyrrhotite as veinlets or stringers. Hole 34409 intersected mafic metavolcanic, chlorite schist and graphitic schist with 5% pyrite and possibly trace sphalerite. Two further holes, 34446 and 34449 totaling 111.9 m, bracketed 34409 further testing the strike continuity. No assays were originally reported, but a later geophysical report records a 1.6 g Au/t over 0.35 m as the reason for Inco staking a block of 9 claims over the drill holes in 1989 (Berrer,1991).

Gridding of the claim block was followed by a ground magnetic and horizontal loop survey. The EM results were weak to medium strength and interpreted to represent a graphitic shear or minor sulphides (Berrer, 1991). Geological mapping completed in 1990 indicated the claims were underlain by mafic to intermediate metavolcanic rocks and diabase (McEachern, 1991). No significant sulphide mineralization was observed, and the best assay was 15 ppb Au from an intermediate metavolcanic unit, and 291 ppm Zn from a mafic metavolcanic flow.

This showing is located on a series of north east trending HLEM anomalies which would appear to correlate with possible splays of the GLDZ or a major north west trending regional fault. An interpretation of the connection between the Ruffo Lake showing and the gold showings on Garden Lake is hampered by the intervening diabase sill located south of McMullen Lake.

Kearns Road

A new gold occurrence discovered by this project consists of a series of veins is exposed in a single location along the east side of the stream leading into the south end of Kearns Lake. The veins are white quartz, 2 to 3 cm in width with 3 to 5 % fine to very fine grained disseminated pyrite, and up to 25% iron carbonate. The veins are hosted by sheared and chloritized mafic metavolcanic rocks containing 2 to 3% very fine grained disseminated pyrite. Two samples were collected with the following results:

Sample Number	Assay (ounces Au / t)	Rock Type	Mineralization
372v	n.d.	white quartz with iron carbonate	3 to 5% fine grained pyrite
372w	0.69	sheared, mafic metavolcanic	2 to 3% very fine grained pyrite
372w	0.61	duplicate	
372w	n.d.	check assay from same pulp	

The veins are oriented in two directions, trending 024° dipping 45° along the length of the stream valley and trending 214° dipping 53°. The stream valley is steep sided and interpreted to be fault controlled. The north east orientation is subparallel to the interpreted contact with the

granitoid rocks to the south, and the western extension of the GLDZ. The north trending orient is similar to the proposed orientation of the fault trending under Conick Lake.

SULPHIDE / BASE METALS

The initial exploration for base metals in the Garden Lake belt was done by Ruffo Lake Mines with the drilling of a series of holes scattered through the eastern portion of the belt (Stocking, 1962). Two holes, not associated with mineralization, were drilled along the north east side of Garden Lake, intersecting andesite, slightly graphitic tuff, sheared dacite, and sericite-chlorite-carbonate schist. The distribution of the holes in areas of little outcrop suggests that the targets being tested were EM anomalies. In 1991, Weaver Lake Resources had an airborne EM and magnetic survey flown in the Mooseland area which outlined a series of EM conductors coincident with the Ruffo Lake drill holes (Pitman, 1991).

A belt wide exploration program for base metals was initiated with an airborne EM and magnetic survey by Inco, Canadian Nickel Company or Canico, in 1963 (Berrer, 1990). The better electromagnetic responses, often those with a coincident magnetic response, were investigated by reconnaissance ground magnetometer and vertical loop electromagnetic surveys in 1966. The best anomalies located by the ground surveys were tested by diamond drilling in 1966 and 1967 with a series of drill holes, of which 13 holes are recorded in the assessment files.

Starting in 1983, C. Bumbu outlined sulphide mineralization in the area north of Garden Lake. A property covering the mineralization has been explored by a two different companies, and by the partnership of C. Bumbu and J. Martin.

Mooseland Area

A series of 8 diamond drill holes, totaling 380.7 m, were completed by Ruffo Lake Mines in the area north of the Mooseland River, east of Garden Lake (Stocking,1962). Six of the holes intersected a northern horizon of graphitic tuff with numerous quartz and calcite stringers and 3 to 5% stringer to bleb sulphide. Holes 14-B-1 and 14-B-2 intersected andesite with 10 to 90% pyrite and pyrrhotite and 5 to 10% magnetite bounded by a 3 inch chlorite matrix breccia and a 7.6 cm wide carbonate matrix breccia. Hole 14-B-1 also intersected approximately 4 m of 50% sulphide and 1.8 m of massive sulphide. These two holes are located north of a rubble pile along the north side of highway 811, containing subrounded boulders of sulphides. A description by Lavigne et al. (1990), based on samples from the rubble and an exposure in the roadside ditch, indicated that the sulphides are massive to brecciated pyrrhotite with disseminated pyrite. Significant amounts of euhedral magnetite were noted to rim some of the rock fragments. Analysis of the sulphides from the rubble pile returned 19 ppb Au, 335 ppm Zn, 90 ppm Cu and 66 ppm Ni (Lavigne et al., 1990). The bedrock exposure of the sulphide zone reported by Lavigne et al (1989) was not located during this mapping program. The eastern most Ruffo Lake Mines holes intersected zones of up to 20% pyrite and pyrrhotite in andesite next to the diabase contact. These two holes also collared in a granite, observed in outcrop to the north, and all of the holes in this area had feldspar porphyry dykes, possible related to the granite. The western most holes intersected a separate southern horizon described as fine grained basalt with 5 to 100% pyrite and pyrrhotite and magnetite in short sections of up to 30%, and commonly as blebs or patches throughout. No assays were reported for this work.

Following a belt wide geophysical survey, Inco drilled a series of 5 holes, totaling 271.3 m, south of the Ruffo Lake Mines drill holes in 1966 and 1967. The western most hole, 34412, intersected chlorite and quartz chlorite schist containing quartz seams with graphite. Up to 15%

pyrite was reported for one narrow section. Further east, the northern two holes, 30691and 30692, intersected diabase over their entire length. The southern two holes, 30694 and 34411, intersected chlorite schist, quartz graphite schist and rhyolite with up to 25% pyrite and pyrrhotite as stringers in the more graphite rich sections. These units may be the same as the rocks exposed at the Gate showing.

In 1991, Weaver Lake Resources completed a Geoterrex Geotem II time domain EM system over the area of the Ruffo Lake Mines drill holes (Pitman, 1991). Two EM trends were outlined, a series of discontinuous northern conductors coincident with magnetic anomalies, and a continuous southern trend. The Ruffo Lake Mines drill holes are located on the northern conductors, and the Inco holes are situated on the southern conductors. The southern conductors are interpreted to represent the eastern extension of the GLDZ, located under the Mooseland River (*see* "Structure").

Gate

Ruffo Lake Mines drilled 2 holes, totaling 61.7 m, to the east of the Kitchen Lake road in 1962 (Stocking 1962). These holes intersected graphitic tuffs with 15 to 20% quartz stringers, but no assays are reported. Cherty andesitic metavolcanic rocks are exposed in the area of the stream, at the current position of the gate on the Kitchen Lake road. The mafic metavolcanic rock hosts a sulphide-bearing breccia containing 15 to 20% fine grained pyrite in a chloritic matrix with angular fragments of cherty material. Assay results were not anomalous in base metals (sample 378; Table 4). Sulphides are also reported in a trench on the east side of the stream, north of the Gate showing but no assays have been recorded. These units are unconformably overlain by diabase sills and only exposed at the base of the hills, on the edge of the swamp. The intensely sheared and iron carbonate altered units compared to the Bluff showing (*see* "Economic Geology – Gold") are located on the east side of the stream. This showing is also interpreted to be located in the eastern extension of the GLDZ.

Bumbu

The initial activity in this area was by Ruffo Lake Mines who completed a single diamond drill hole, to a depth of 30.8 m, in the area north of Garden Lake in 1962 (Stocking, 1962). This hole is located about 150 m south of the main series of trenches at the Bumbu showing. The hole intersected basalt, and a 3.4 m wide, light gray coloured iron formation consisting of mainly chert with minor magnetite. No assays are reported.

Starting in 1983, C. Bumbu prospected in the Garden Lake belt following the clear cut logging, and outlined sulphide mineralization north of Garden Lake. Subsequent pitting and blasting exposed basalts, iron formation and sulphide lenses on two parallel horizons. Claims covering this mineralization were part of a larger property optioned to Garden Lake Resources in 1988. This area was not actively explored, but was covered by the helicopter borne Aerodat EM and magnetic survey (Junnila, 1988). Additional prospecting, pitting and blasting of a series of trenches on the northern EM anomalies, and a solitary trench on the southern anomaly was completed.

In 1991, Weaver Lake Resources completed a program of gridding, horizontal loop EM and magnetic surveys, further prospecting and trenching (Pitman, 1991). Detailed mapping and sampling was initiated, complimented by a thin section study. The units in the trenches are described as a chloritized and brecciated stringer sulphide zone located at the contact between pillowed mafic metavolcanic and felsic metavolcanic rocks. Along strike with the stringer zone

are massive sulphide lenses varying from 0.6 to 0.8 metres in width, and hosted by altered mafic metavolcanic rocks and metasediments / felsic tuffaceous rocks. Sulphide bearing siliceous metasediments and banded cherty-magnetite iron formation are located further along strike to the east, in the Conick Lake area. The metavolcanic rocks are highly altered and recrystallized obscuring the original rock types. The mafic metavolcanic rocks are described as being hornblende, chlorite, plagioclase, quartz, epidote, with minor opaques, typical of upper greenschist facies regional metamorphism. A sample from the easternmost northern trench contained an amphibole rich unit composed of Ti-hornblende/actinolite with minor plagioclase, quartz, biotite, and chlorite. This unit was interpreted to be a metamorphosed calcareous sediment or tuff. The whole sequence is capped by pillowed mafic metavolcanic rocks to the south. A grab sample assaying 6.11% Cu and 983 ppm Zn was collected from the southern trench (Pitman, 1991). Generally, samples from the northern trenches ranged from 71 to 260 ppm Cu and <50 to 163 ppm Zn.

The property was visited by the Resident Geologist and staff, and a number of samples were collected (Lavigne et al., 1992). The sulphides are described as being massive lenses to disseminated aggregates located in a zone overlying a silicified horizon to the north, and an anthophyllite rich unit along strike to the east. The best assay was 440 ppm Cu, 76 ppm Zn, 244 ppm Co, 0.004 oz Au/t from a grab sample.

Further work was conducted by C. Bumbu in partnership with J. Martin. In 1993, C. Bumbu completed a prospecting, trenching and blasting program and collected 34 samples (McEachern, 1994). The assays returned up to 0.02 oz Au/t, 0.17% Ni and 526 ppm Cu. In 1997, J. Martin conducted a program of power stripping and blasting enlarging the trenches (Martin 1997). Sampling of rocks from the trenches returned a best assay of 0.01 oz Au/t and 415 ppm Cu in the southern trench.

The rocks currently exposed in the trenches are highly oxidized and rust stained obscuring many of the fine features. A series of massive, gabbroic textured flows and pillowed flows with rare flow top breccias and 5 to 10 cm wide iron formations are exposed in the trenches. The massive flows are usually metamorphosed to an upper greenschist to lower amphibolite facies containing medium to coarse grained hornblende. The chert – magnetite iron formation commonly caps the flow top breccia, but south of the road the iron formation also occurs as interpillow lenses. The sulphide mineralization is associated with iron formation and flow top breccias, and consists of massive to semi-massive 0.2 to 0.3 m wide lenses of pyrite and pyrrhotite with minor chalcopyrite. The lenses occur in highly fractured massive to pillowed mafic metavolcanics, often in close proximity to thin beds of iron formation. The silicified horizons were not observed in the trenches but occur stratigraphically above and below the sulphide mineralized units. The sulphide – iron formation association, and strata-bound silicification is interpreted to indicate a hydrothermal origin for the sulphides, with later remobilization into fractures during metamorphism and deformation. The hydrothermal activity probably continued to a lesser degree after deposition of these units as sulphide was observed in originally porous units overlying the trenches. This includes 2 to 3 cm fragments of sulphide in flow top breccia and 1 to 2 % fine grained pyrite in interpillow hyaloclastite south of the trenches, and interpillow pyrite along strike west of Conick Lake. Five samples of the heavily mineralized to semi-massive sulphide mineralization were collected from the trenches (samples 18a, b, tr2, tr3, tr4; Table 4). The best assay was 958 ppm Cu, 180 ppm Zn, 148 ppm Ni in a semi-massive sulphide sample.

Daniels

The occurrence of small sulphide lenses in mafic metavolcanic rocks on the south shore of a small lake, located west of the northwest corner of Kearns Lake, was described by Milne (1964). The lenses of pyrrhotite and quartz are hosted by magnetic mafic tuff containing disseminated pyrrhotite. There was no record of any work in this area until G. Daniels conducted some prospecting along the Madden Lake Road, west of Kearns Lake (Daniels, 1989). The metavolcanic rocks are reported to be a dark green amphibole-chlorite rock, containing thinly disseminate pyrrhotite, rusty fragments and small vuggy quartz lenses. Further prospecting conducted by Kwiatkowski and Kukkee in the same area uncovered a mineralized zone containing pyrite and chalcopyrite (Kwiatkowski, 1991). Assays returned minimal values of zinc and nickel.

West Garden

The description for this pyroxenite contained above (*see* "Mafic to Ultramafic Intrusive Rocks - Pyroxenite"). Inco drilled a hole on a coincident magnetic high – EM conducted close to the pyroxenite in 1966. This hole was 36.6 m long, and intersected 1.2 m of amphibolite with magnetite followed by a series of graphitic metavolcanic rocks with 2 to 10% sulphide. No assays were reported.

Recommendations

The Garden Lake belt has the potential to host gold, PGE, and VMS mineralization, and each type of mineralization is associated with a set of features useful as guides for exploration. A number of areas with these features, and little to no past exploration, were noted during this mapping program. A number of other areas have been explored to a limited extent and are still considered to have potential to host significant mineralization.

GOLD

A major problem in many of the gold showings in the belt has been the discrepancy between the grab samples and the detailed sampling (e.g. Phelan, 1946; Junnila, 1989; Stares, 1997a, b). These discrepancies are interpreted to indicate that the fine scale controls on gold mineralization are not well understood. It is recommended that any detailed sampling program be conducted using shorter sample lengths, larger assay weights (possibly one assay ton), duplicate samples, and/or metallic separates. Once the fine scale controls are understood, gold exploration in the belt will be more successful.

Gold mineralization in the Garden Lake belt is associated with:

- late structures, both ductile and brittle, in either north or east trending
- iron carbonate alteration, both pervasive and in fractures associated with quartz
- sulphides, generally pyrite with minor arsenopyrite and/or pyrrhotite and associated with iron carbonate alteration
- arsenic, geochemically anomalous (thousands of ppm) to major constituent (arsenopyrite).

The most favourable gold targets or under-explored areas are:

- eastern extension of the Garden Lake Deformation Zone (GLDZ), host to a number of iron carbonate altered, highly sheared, sulphide rich mafic to intermediate metavolcanic units resembling the gold showings on Garden Lake; this area is along strike with the lake sediment anomalies in the eastern end of the belt reported by Jackson and Dyer (2000).
- west along the southwest margin of the belt in the area south of Kearns Lake along the possible western extension of the GLDZ and the north trending cross faults; this area hosts the new gold occurrence hosted by iron carbonate - quartz vein with pyrite.
- the northeast trending fault between McMullen and Ruffo Lake, a possible splay of the GLDZ, in the area explored by Inco in 1967 and 1991.
- the better induced polarization anomalies along the GLDZ under Garden Lake.

BASE METALS

There are two different environments with the potential to host volcanogenic massive sulphide (VMS) mineralization. Along the north side of the belt, the association of sulphide mineralization with iron formations, and silicification and actinolite-biotite-garnet alteration of some metavolcanic units indicates a high degree of hydrothermal activity. The proposed submarine eruptive environment for the mafic flows, and the lack of felsic flows or tuffs, is indicative of a mafic type VMS system (Barrie and Hannington, 1997). The style of mineralization would be Cu-rich and Pb-poor. A thin felsic tuffaceous unit located south of Kearns Lake has an FII-FIIIa type lithogeochemical signature (*see* "Lithogeochemistry"). This lithogeochemical signature is typical of the bimodal-mafic type VMS system (Barrie and Hannington, 1997) with a Cu-Zn style of mineralization.

In addition, all of the holes drilled to date testing the EM conductors associated with the sulphide occurrences have been shallow. The base metal contents of the sulphide occurrences is sub-economic, but some base metal deposits are capped by significant volumes of barren sulphide (e.g. Normetal – 10 m tonnes of 0.79% Zn, 5.3% Zn, 0.8 g/t Au capped by 10 m tonnes of pyritic material; Chartrand and Cattalani, 1990).

The most favourable base metal targets in the belt are:

- the area of the sulphide boulders, coincident with the airborne EM conductors, north of the Mooseland River.
- the area south west of Kearns Lake hosting a silicified FII – FIIIa type felsic metavolcanic, minor anomalous base metal sulphide mineralization, and an iron formation.

PLATINUM GROUP ELEMENTS

The Garden Lake belt borders the Roaring River Complex (Figure 1 and 2), a diorite to granodiorite intrusion with gabbro to pyroxenite lenses (Stern and Hanson, 1991). This complex is one of the many intrusions containing rocks of the sanukitoid suite (Stern et al., 1989). Recent work has shown that sanukitoid bearing intrusions have the potential to host PGE mineralization (e.g. Entwine Lake: Stone and Hallé, 1999). The factors controlling the distribution of these intrusions are not well understood and the size of the intrusions is highly variable and not well exposed (e.g. Samuels Lake: N. Pettigrew, personal communication).

Additional sampling of the late gabbro intrusions and the pyroxenite is required to properly establish their potential to host PGE mineralization.

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Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

***Note:** Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.*

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